Established by BENJAMIN SILLIMAN in 1818.

THE

AMERICAN

JOURNAL OF SCIENCE.

EDITORS

JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS JOSIAH P. COOKE, GEORGE L. GOODALE AND JOHN TROWBRIDGE, OF CAMBRIDGE.

PROFESSORS H. A. NEWTON AND A. E. VERRILL, OF NEW HAVEN,

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

THIRD SERIES.

VOL. XXXIX.—[WHOLE NUMBER, CXXXIX.]

No. 231.—MARCH, 1890.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1890.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

GEO. L. ENGLISH & CO.'S

MINERALS.

RECENT ADDITIONS.

Japanese Topaz, Orthoclase, &c.

Chili Iron Sulphates, including the new species **Amarantite,** also **Roemerite, Coquimbite** and **Copiapite.**

Flos Ferri,
Yellow Wulfenite, } from New Mexico.
Descloizite,

Azurite and **Malachite,** a very fine lot just received; also good pseudomorphs of **Malachite** after **Azurite.**

Antwerp, N. Y., Minerals, including fine **Millerite, Chalcodite, Przibramite, Siderite** and **Ankerite.**

Chiastolite in excellent sections, and a few doubly terminated crystals.

Octahedral Pyrite Crystals from French Creek, extra fine.

Chalcopyrite, both in loose crystals of rare and interesting forms, and in groups of superb iridescent crystals.

Yttrialite, Cyrtolite, Thorogummite, Fergusonite, Allanite, Gadolinite, Tengerite, and other rare minerals described in Dec. No. of American Journal of Science, from Texas.

Mexican Topaz, Calcite, &c.

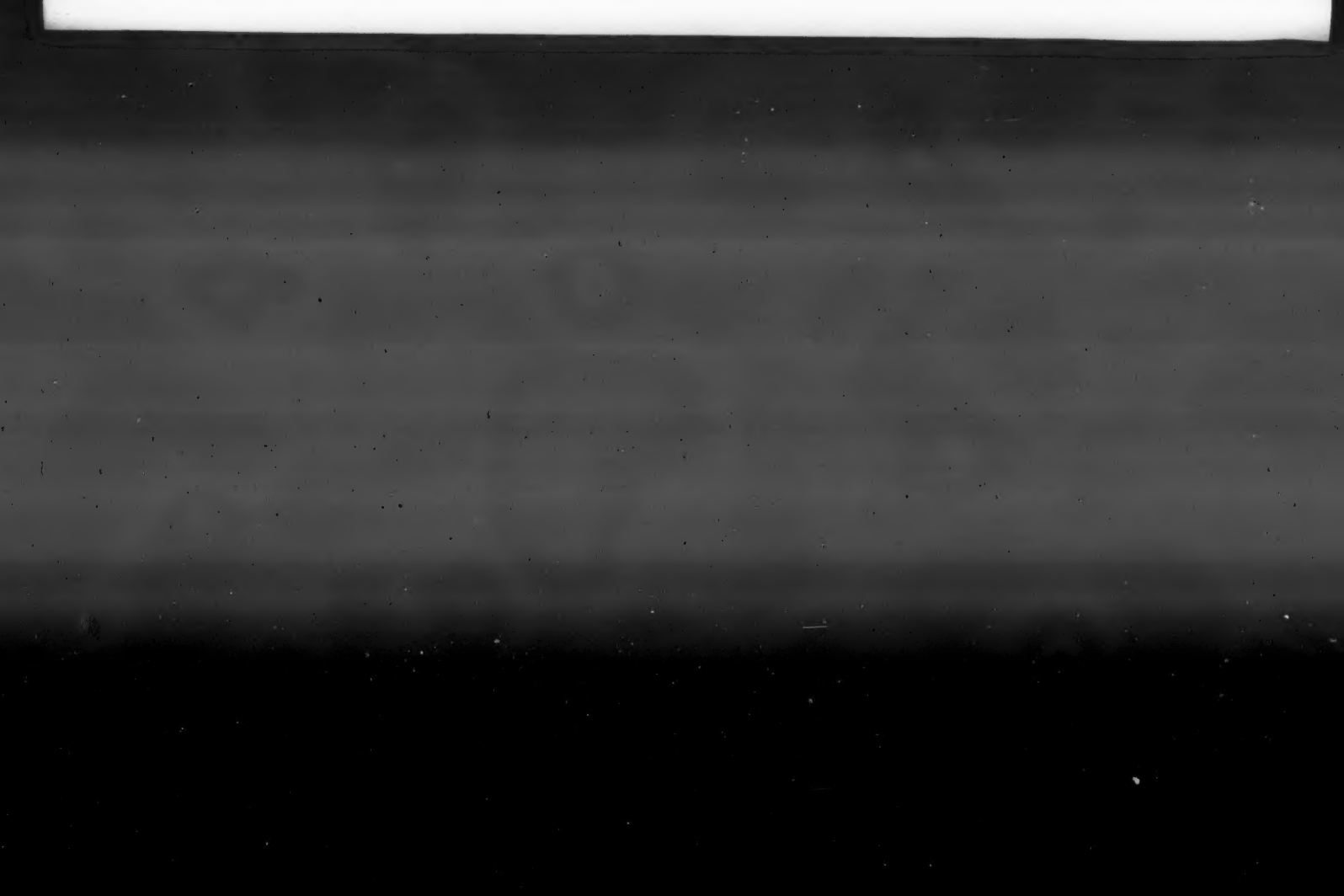
REMEMBER, ALSO,

That our general stock of Minerals is unquestionably the largest, finest, most varied and complete in the country. It includes very many of the rarest species and large numbers of desirable species, such as Vanadinite, Wulfenite, Brochantite, Clinoclasite, Tyrolite, Conichalcite, Zunyite, Phenacite, Bertrandite, Salida, and Nathrop and Alaska Garnets; Arkansas Brookite, Rutile, Aegirite, Quartz, &c.; Jarosite, Chalcanthite, English Calcite, Fluorite, Barite, Hematite, &c., &c.

CATALOGUE FREE.

GEO. L. ENGLISH & CO., Dealers in Minerals,

1512 Chestnut Street, - - Philadelphia, Pa.



THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. XXII.—Sedgwick and Murchison: *Cambrian and Silurian;* by James D. Dana.

Erroneous impressions have long existed among American geologists with regard to the relations to one another, and to Cambrian and Silurian geology, of Sedgwick and Murchison. The Taconic controversy in this country served, most unreasonably, to intensify feelings respecting these British fellow-workers in geology, and draw out harsh judgments. Now that right views on the American question have been reached, it is desirable that the facts connected with the British question should be understood and justly appreciated.

Sedgwick and Murchison were literally fellow-workers in their earlier investigations. Professor John Phillips, in a biographical sketch of Sedgwick,* whose intimate friendship through fifty years "he had the happiness of enjoying," speaks thus, in 1873, of their joint work:

"Communications on Arran and the north of Scotland, including Caithness (1828) and the Moray Firth; others on Gosau and the eastern Alps (1829–1831); and still later, in 1837, a great memoir on the Palæozoic strata of Devonshire and Cornwall, and another on the coeval rocks of Belgium and North Germany, show the labors of these intimate friends in the happiest way—the broad generalizations in which the Cambridge professor delighted, well supported by the indefatigable industry of his zealous companion."

* Nature, Feb. 6, 1873, vii, 257.

Professor Phillips then speaks of the Cambrian and Silurian labors "of two of the most truly attached and mutually helpful cultivators of geological science in England."

Of these Cambrian and Silurian labors it is my purpose to give here a brief history derived from the papers they published. They were begun in 1831, without concert—Sedgwick in Wales, Murchison along the Welsh and English borders.

In September of 1831, the summer's excursions ended, Murchison made his first report at the first meeting of the British Association. It was illustrated by a colored geological map representing the distribution of the "Transition rocks," the outlying Old Red Sandstone, and the Carboniferous limestone.*

These "Transition Rocks" (of Werner's system), upturned semi-crystalline schists, slates and other rocks, passing down into uncrystalline, and regarded as mostly non-fossiliferous, the "*agnotozoic*" of the first quarter of the century, were the subject of Sedgwick's and Murchison's investigations—the older of the series, as it turned out, being included in Sedgwick's part.† They were early resolved into their constituent formations by Murchison, and later as completely by Sedgwick in his more difficult field.‡

Already in March and April of 1833, Murchison showed, by his communications to the Geological Society of London, that he had made great progress; for the report says:§ He "separated into distinct formations, by the evidence of fossils and the order of superposition, the upper portion of those vast sedimentary accumulations which had hitherto been known only under the common terms of Transition Rocks and Grauwacke." And these "distinct formations" were: (1) the Upper

* Murchison, Report of the British Association, i, 91, 1831.

† Murchison says, in the introductory chapter of his Silurian System, p. 4, "No one [in Great Britain, before his investigations began] was aware of the existence below the Old Red Sandstone of a regular series of deposits containing peculiar organic remains." "From the days of De Saussure and Werner, to our own, the belief was impressed on the minds of geologists that the great dislocations to which these ancient rocks had been subjected had entirely dissevered them from the fossiliferous strata with which we were acquainted."

‡ The term "Transition" early appeared in American geological writings. Sixty to seventy-five years ago it was applied by Maclure, Dewey and Eaton to the rocks of the Taconic region and their continuation; for these were upturned, apparently unfossiliferous, semi-crystalline to uncrystalline, and extended eastward to a region of gneisses. The study of the rocks was commenced; but in 1842, before careful work for the resolution of them had been done—like that in which Murchison and Sedgwick were engaged—they were, unfortunately, put, as a whole, into a "Taconic system" of assumed pre-Potsdam age; at the same time "Transition" was shoved west of the Hudson, over rocks that were horizontal, and already resolved. Owing to this forestalling of investigation, and partly also to inherent difficulties, the right determination of the several formations comprised in this Taconic or "Transition" region was very long delayed.

§ Murchison, Proceedings of the Geol. Soc. London, i, 470, 474, 1833, in a paper on the Sedimentary deposits of Shropshire and Herefordshire.

Ludlow rocks; (2) the Wenlock limestone; (3) the Lower Ludlow rocks; (4) Shelly sandstones, "which in Shropshire occupy separate ridges on the southeastern flanks of the Wrekin and the Caer Caradoc"; (5) the Black Trilobite flagstone whose "prevailing Trilobite is the large *Asaphus Buchii*, which with the associated species," he observed, "is never seen in any of the overlying groups;" and, below these, (6), Red Conglomerate sandstone and slaty schist several thousand feet in thickness.

By the following January, 1834, Murchison was ready with a further report,* in which he described the "four fossiliferous formations" in detail, and displayed, on a folded table arranged in columns, their stratigraphical order, thickness, subdivisions, localities, and "characteristic organic remains." The subdivisions of the rock-series in the memoir are as follows, commencing above: I, Ludlow rocks, 2,000 feet; II, Wenlock and Dudley rocks, 1,800 feet; III, Horderley and May Hill rocks (afterward named Caradoc), 2,500 feet; IV, Builth and Llandeilo flags, characterized by *Asaphus Buchii*, 1,200 feet; and, below these, V, the Longmynd and Gwastaden rocks, many thousand feet thick, set down as unfossiliferous.

Thus far had Murchison advanced in the development of the Silurian system by the end of his third year. Upper and Lower Silurian strata were comprised in it, but these subdivisions were not yet announced.

During the interval from 1831 to 1834, Sedgwick presented to the British Association in 1832 a verbal communication on the geology of Caernarvonshire, and another brief report of progress in 1833. A few lines for each are all that was published. The difficulties of the region were a reason for slow and cautious work.

In 1834, as first stated in the Journal of the Geological Society for the year 1852, the two geologists took an excursion together over their respective fields. Sedgwick says:† "I then studied for the first time the Silurian types under the guidance of my fellow-laborer and friend; and I was so struck by the clearness of the natural sections and the perfection of his workmanship that I received, I might say, with implicit faith everything which he then taught me." And further, "the whole 'Silurian system' was by its author placed *above* the great undulating slate-rocks of South Wales." The geologists next went together over Sedgwick's region, and the sec-

* Murchison, Proc. Geol. Soc., ii, 13, 1834. The subject was also before the British Association: Report for 1834, p. 652.

† Sedgwick, Quarterly Journal of the Geological Society, viii, 152, 1852.

tions from the top of the Berwyns to Bala. Murchison concluded, after his brief examination, and told Sedgwick, that the Bala group could not be brought within the limits of his system. He says: "I believed it to plunge under the true Llandeilo flags with *Asaphus Buchii* which I had recognized on the east flank of that chain." "Not seeing, on that hurried visit, any of the characteristic Llandeilo Trilobites in the Bala limestone, I did not then identify that rock with the Llandeilo flags, as has since been done by the Government surveyors."*

In 1835, the terms "Silurian" and "Cambrian" first appear in geological literature. Murchison named his system the "Silurian" in an article in the Philosophical Magazine for July of that year, and at the same time defined the two grand subdivisions of the system: I, the *Upper Silurian*, or the Ludlow and Wenlock beds; and II, the *Lower Silurian*, or the Caradoc and Llandeilo beds.†

During the next month, August, the fourth meeting of the British Association was held at Edinburgh, and in the report of the meeting,‡ the two terms, *Silurian* and *Cambrian*, are united in the title of a communication "by Professor Sedgwick and R. I. Murchison," the title reading, "On the Silurian and Cambrian systems, exhibiting the order in which the older sedimentary strata succeed each other in England and Wales." Murchison, after explaining his several subdivisions, said that "in South Wales" he had "traced many distinct passages from the lowest member of the 'Silurian system' into the underlying slaty rocks now named by Professor Sedgwick, the Upper Cambrian." Sedgwick spoke of his "*Upper Cambrian group*" as including the greater part of the chain of the Berwyns, where he said, "it is connected with the Llandeilo flags of the Silurian and expanded through a considerable part of South Wales;" the "*Middle Cambrian group*" as "comprising the higher mountains of Caernarvonshire and Merionethshire;" the "*Lower Cambrian group*" as occupying the southwest coast of Caernarvonshire, and consisting of chlorite and mica schists, and some serpentine and granular limestone; and finally, he "explained the mode of connecting Mr. Murchison's researches with his own so as to form one general system."

Thus, in four years Murchison had developed the true system in the rocks he was studying; and Sedgwick likewise had reached what appeared to be a natural grouping of the rocks of his complicated area. Further, *in a united paper*, or papers presented together, they had announced the names Silurian and Cambrian, and expressed their mutual satisfaction with the

* Murchison, Q. J. G. Soc., viii, 175.
† Phil. Mag., vii, 46, July, 1835.
‡ Brit. Assoc., v, August, 1835.

defined limits. Neither was yet aware of the unfortunate mischief-involving fact that the two were overlapping series.

It is well here to note that *the term "Cambrian" antedates "Taconic" of Emmons by seven years;* and also that Emmons did not know—any more than Sedgwick with regard to the Cambrian—that his system of rocks was in part Lower Silurian, and of Llandeilo and Caradoc age.

In May, of 1838, nearly three years later, Sedgwick presented his first detailed memoir on North Wales and the Cambrian rocks to the Geological Society.* Without referring to the characteristic fossils, he divides the rocks below the Old Red Sandstone, beginning below, into (I) the PRIMARY STRATIFIED GROUPS, including gneiss, mica schist and the Skiddaw slates, giving the provisional name of *Protozoic* for the series should it prove to be fossiliferous, and (II) the PALÆOZOIC SERIES; the latter including (1) the Lower Cambrian (answering to Middle Cambrian of the paper of 1835), (2) the Upper Cambrian and (3) the *Silurian*, or the series so called by Murchison. Without a report on the fossils, no comparison was possible at that time with Murchison's Silurian series. Yet Sedgwick goes so far as to say that the "Upper Cambrian," which "commences with the fossiliferous beds of Bala, and includes all the higher portions of the Berwyns and all the slate-rocks of South Wales which are below the Silurian System," "appears to pass by insensible gradation into the lower division of the Upper System (the Caradoc Sandstone);" and that "many of the fossils are identical in species with those of the Silurian System."† Respecting the *Silurian System* he refers to the abstracts of Mr. Murchison's papers and "his forthcoming work."

The *Protozoic* division included the "Highlands of Scotland, the crystalline schists of Anglesea and the Southwest Coast of Caernarvonshire." It is added: "The series is generally without organic remains; but should organic remains appear unequivocally in any part of this class they may be described as the Protozoic System."

In the later part of the same year, 1838, Murchison's "Silurian System" was published‡—a quarto volume of 800

* An abstract appeared in the Proc. Geol. Soc., ii, 675, 1838. A continuation of the paper appeared in 1841, ibid., iii, 541. See also Q. J. Geol. Soc, viii, 1852.

† Of these fossils, he had mentioned "*Bellerophon bilobatus, Producta sericea* and several species of *Orthis*" as occurring in the Bala limestone, "all of which are common to the Lower Silurian System," in a Syllabus of his Cambridge lectures, published in 1837.

‡ Murchison's "Silurian System" bears on its title page the date 1839. He states in the Q. J. Geol. Soc., viii, 177, 1852, that the work was really issued in 1838. The fossil fishes of the volume were described by Agassiz, the trilobites, by Murchison, and the rest of the species, by Sowerby.

pages, with twenty-seven plates of fossils, and nine folded plates of stratigraphical sections, besides many plates in the text—the outcome of his eight years of work. Five hundred pages are devoted to the Silurian System.

The dedication is as follows:

"To you, my dear Sedgwick, a large portion of whose life has been devoted to the arduous study of the older British rocks, I dedicate this work.

Having explored with you many a tract, both at home and abroad, I beg you to accept this offering as a memorial of friendship, and of the high sense I entertain of the value of your labours."

Through Murchison's investigations here recorded, as he remarks in his Introduction with reasonable satisfaction, "a complete succession of fossiliferous strata is interpolated between the Old Red Sandstone and the oldest slaty rocks." He observes as follows of Sedgwick: "In speaking of the labours of my friend, I may truly say, that he not only shed an entirely new light on the crystalline arrangement or slaty cleavage of the North Welsh Mountains, but also overcame what to most men would have proved insurmountable difficulties in determining the order and relations of these very ancient strata amid scenes of vast dislocation. He further made several traverses across the region in which I was employed; and, sanctioning the arrangement I had adopted, he not only gave me confidence in its accuracy, but enhanced the value of my work by enabling me to unite it with his own; and thus have our joint exertions led to a general view of the sequence of the older fossiliferous deposits." In accordance with these statements many of the descriptions and the very numerous sections represent the Cambrian rocks lying beneath the Silurian, —though necessarily with incorrect details, since neither Murchison nor Sedgwick had then any appreciation of the actual connection between the so-called Cambrian and Silurian.

The Silurian system, as here set forth, is essentially that of Murchison's earlier paper of 1835; and through the work, as each region is taken up, the rocks of the *Upper* and *Lower* divisions, and their several subdivisions, are described in order, with a mention of the characteristic fossils As to the relations of the two grand divisions, he says that "although two or three species of shells of the Upper Silurian rocks may be detected in the Lower Silurian, *the mass of organic remains in each group is very distinct.*" Later he makes the number of identical species larger; but even the newest results do not increase it so far as to set aside Murchison's general statement of 1838.

Sedgwick, with all the light which the fossils of the "Silurian System" were calculated to throw on his Upper Cambrian series, found in the work no encroachments on his field or on his views. They were still side by side in their labors among the hitherto unfathomed British Paleozoic rocks.

In 1840 and 1841 Murchison was in Russia with M. de Verneuil and Count Keyserling, and also in Scandinavia and Bohemia, seeking to extend his knowledge of the older fossiliferous rocks and verify his conclusions; and in 1845 the great work on the Geology of Russia and the Urals came out, with a further display of Upper and Lower Silurian life. In his Presidential addresses of 1842 and 1843, reviewing the facts in the light of his new observations, he went so far as to say that the Lower Silurian rocks were the oldest of fossiliferous rocks and that the fossiliferous series of North Wales seemed to exhibit no vestiges of animal life different from those of the Lower Silurian group.

Still Sedgwick made no protest. He states definitely on this point in his paper of 1852,* that from 1834, the time of the excursion with Murchison, until 1842, he had accepted Murchison's conclusions, including the reference of the Meifod beds to the Caradoc or Silurian, without questioning; but that from that time, 1842, he began to lose his confidence in the stability of the *base-line* of the "Silurian System." He adds that in 1842, Mr. Salter, the paleontologist, informed him that the Meifod beds were on the same horizon nearly with the Bala beds; and he accepted this conclusion to its full extent, using the words "if the Meifod beds were Caradoc, the Bala beds must also be Caradoc or very nearly on its parallel." Thus the inference of Murchison was adopted and discrepancy between them deferred. And on the following page he acknowledges that all his papers of which there is any notice in the Proceedings or Journal of the Geological Society between 1843 and 1846 admit this view as to the Bala beds and certain consequences of it—"mistakes" as he pronounced them six years later, in 1852.†

In 1843, Sedgwick read before the Geological Society in June, a paper entitled *An Outline of the Geological Structure of North Wales*, which was published in abstract in the Proceedings (iv, 251); and in November of the same year, one *On the Older Palæozoic* (*Protozoic*) *Rocks of North Wales* (from observations by himself in company with Mr. Salter), which appeared, with a map, in the Journal of the Geological Society (i, 1). The abstract in the Proceedings was prepared by Mr. Warburton, the President of the Geological Society, and the paper of the following November, makes no allusion to this fact, or any objection to the abstract.

* Q. J. Geol. Soc., viii, 153, 1852. † Ibid., p. 154.

A remarkable feature of the November paper is that it nowhere contains the term *Upper Cambrian or even Cambrian*, although the rocks are Sedgwick's Upper Cambrian, together with Murchison's Upper Silurian.

A second fact of historical interest is the use of the term "Protozoic," not in the sense in which it was introduced by him in 1838, but in that in which introduced in 1838 by Murchison, on page 11 of his Silurian System, where he says:

"But the Silurian, though ancient, are not, as before stated, *the most* ancient fossiliferous strata. They are, in truth, but the upper portion of a succession of early deposits which it may hereafter be found necessary to describe under one comprehensive name. For this purpose I venture to suggest the term *Protozoic Rocks*, thereby to imply the first or lowest formations in which animals or vegetables appear."

These facts are in accordance with Sedgwick's acknowledgment, mentioned on the preceding page.

The map accompanying the paper as originally prepared, had colors corresponding to five sets of areas, those of the "Carboniferous Limestone," "Upper Silurian," "Protozoic" Rocks, "Mica and Chlorite Slate," "Porphyritic Rocks;" and here again Cambrian, Upper or Lower, does not appear, the term Protozoic being substituted. The map, as it stands in the Journal of the Geological Society, has in place of simply *Protozoic*, the words "Lower Silurian (Protozoic)." Sedgwick complains, in his paper of 1852, pages 154, 155, of this change from his manuscript, and attributes it to Mr. Warburton, saying that "the map with its explanations of the colors plainly shows that Mr. Warburton did not comprehend the very drift and object of my paper." "I gave one colour to this whole Protozoic series only because I did not know how to draw a clear continuous line on the map between the upper Protozoic (or lower Silurian) rocks and the lower Protozoic (or lower Cambrian) rocks." "Nor did I ever dream of an incorporation of all the lower Cambrian rocks in the system of Siluria." Sedgwick also says on the same point: "I used the word *Protozoic* to prevent any wrangling about the words Cambrian and Silurian." But this is language he had no disposition to use in 1843, as the paper of 1843 shows.

Page 155 has a foot note. In it the aspect of the facts is greatly changed. He takes back his charges, saying, "I suspect that, in the explanation of the blank portion of the rough map exhibited in illustration of my paper I had written *Lower Silurian and Protozoic*, and that Mr. Warburton, erroneously conceiving the two terms identical, changed the words into Lower Silurian (Protozoic)" "I do not by any means accuse

Mr. Warburton of any *intentional* injustice—quite the contrary; for I know that he gave his best efforts to the abstract. But he had undertaken a task for which he was not prepared, inasmuch as he had never well studied any series of rocks like those described in my papers." Sedgwick here uses Protozoic in the Sedgwick sense, not, as above in the Murchison sense. Sedgwick again in 1854, speaks of "the tampering with the names of my reduced map." But these explanations of his should take the harshness out of the sentence, as it was in 1843 to 1846 out of all his words.

The paper has further interest in its long lists of fossils in two tables: I, "Fossils of the Older Palæozoic (Protozoic) Rocks in North Wales, by J. W. Salter and J. de C. Sowerby," showing their distribution; and II, "Fossils of the Denbigh flagstone and sandstone series."

Thus, until 1846, no serious divergence of views had been noted by Sedgwick. This is manifested in his paper on the Slate rocks of Cumberland, read before the Geological Society on the 7th and 21st of January, 1846,* which says, on the last page but one: "Taking the whole view of the case, therefore, as I know it, I would divide the older Palæozoic rocks of our island into three great groups: 3d, the upper group, *exclusively Upper Silurian;* 2, the middle group, or *Lower Silurian*, including Llandeilo, Caradoc, and perhaps Wenlock; 1, the first group, or *Cambrian;*" differing in this arrangement from Murchison only in the suggestion about the Wenlock. The italics are his own. He adds:

> "This arrangement does no violence to the Silurian system of Sir R. Murchison, but takes it up in its true place; and I think it enables us to classify the old rocks in such a way as to satisfy the conditions both of the fossil and physical as well as mineralogical development."

But before the year 1846 closed not only the overlapping of their work was recognized but also the consequences ahead, and divergence of opinion began.

In December a paper was presented by Sedgwick to the Geological Society on "the Fossiliferous Slates of North Wales, Cumberland, Westmoreland and Lancashire,"† which contains a protest against the downward extension of the Silurian so as to include the Cambrian. It is excellent in spirit and fair in argument. Many new facts are given respecting sections of the rocks in South Wales and North Wales, in some of which occur the Lingula flags, and characteristic fossils are mentioned. In describing some South Wales sections, Sedg-

* Q. J. Geol. Soc., ii, 106, 122, 1846. † Ibid., iii, 133, Dec., 1846.

wick uses the term *Cambro-Silurian* to include, beginning below, (1) "Conglomerates and slates, (2) Lower Llandeilo flags, (3) Slates and grits (Caradoc Sandstone of Noeth Grug, etc., (4) Upper Llandeilo flag passing by insensible gradations into Wenlock shale." The Cambrian series is made to include (1) The Festiniog or Tremadoc group; (2) Roofing slates, etc., the "Snowdonian group," fossiliferous in Snowdon, etc.; (3) the Bala group; and then (4) "the *Cambro-Silurian* group," comprising "the lower fossiliferous rocks east of the Berwyns between the Dee and the Severn—the Caradoc Sandstone of the typical country of Siluria—and the Llandeilo flags of South Wales, along with certain associated slates, flags, and grits." The extension of the term Silurian down to the Lingula flags, or beyond, is opposed because the beds below the Llandeilo are not part of the Silurian system; the term Silurian [derived from the Silures of Southeast Wales and the adjoining part of England] is not geographically applicable to the Cambrian rocks; and because the only beds in North Wales closely comparable "with the Llandeilo flags are at the top of the whole Cambrian series." This last reason later lost its value when it was proved, as Sedgwick recognized years afterward, that Murchison's Llandeilo flags were really older than Sedgwick's Bala rocks.

Sedgwick's paper was followed, on January 6th, with one by Murchison,* objecting to this absorption of the Lower Silurian and reiterating his remark of 1843 that the fossiliferous Cambrian beds were Lower Silurian in their fossils, and arguing, thence, for the absorption of the Cambrian, to this extent, by the Silurian. Having, eight years before, in his great work on the "Silurian System," described the Lower Silurian groups with so much detail, and with limits well defined by sections and by long lists of fossils, over a hundred species in all, many of them figured as well as described, and having thus added a long systematized range of rocks to the lower part of the Paleozoic series, he was naturally unwilling to give up the name of Lower Silurian for that of Upper Cambrian or Cambro-Silurian. Moreover, the term "Silurian," with the two subdivisions of the system, the Upper and Lower, had gone the world over, having been accepted by geologists of all lands as soon as proposed, become affixed to the rocks to which they belonged, and put into use in memoirs, maps and geological treatises.

In 1852, the controversy, begun by encroachments not intended on either part, reached its height. Sedgwick's earnest presentation of the case† and appeal before the Geological

* Q. J. Geol. Soc., iii, 165, Jan., 1847. † Ibid., viii, 152.

Society in February of that year—making the latter part of a memoir by him on the "Classification and Nomenclature of the Lower Palæozoic Rocks of England and Wales"—argues, like that of 1846, for the extension of the Cambrian from below upward to include the Bala beds, and thereby also the Llandeilo flags, and Caradoc sandstone, although, he says "my friend has published a magnificent series of fossils from the Llandeilo flagstone." Sedgwick also expresses dissatisfaction with Mr. Warburton's abstract of his paper of June, 1843, and with the change made in his map of November, 1843, as indicated on page 174, but, as there shown, he has no blame for Murchison and little for Mr. Warburton. He also points out some errors in the stratigraphical sections of the "Silurian System,"—since the publication of which fourteen years had passed. He closes with the words (p. 168):

"I affirm that the name 'Silurian,' given to the great Cambrian series below the Caradoc Group, is historically unjust. I claim this great series as my own by the undoubted right of conquest; and I continue to give it the name 'Cambrian' on the right of priority, and, moreover, as the only name yet given to the series that does not involve a geographical contradiction. The name 'Silurian' not merely involves a principle of nomenclature that is at war with the rational logic through which every other Palæozoic group of England has gained a permanent name, but it also confers the presumed honor of a conquest over the older rocks of Wales on the part of one who barely touched their outskirts and mistook his way as soon as he had passed within them.

"I claim the right of naming the Cambrian rocks because I flinched not from their difficulties, made out their general structure, collected their fossils, and first comprehended their respective relations to the groups above them and below them, in the great and complicated Palæozoic sections of North Wales. Nor is this all,—I claim the name Cambrian in the sense in which I have used it, as a means of establishing a congruous nomenclature between the Welsh and the Cumbrian Mountains, and bringing their respective groups into a rigid geological comparison; for the system on which I have for many years been laboring is not partial and one-sided, but general and for all England."

Sedgwick does not seem to have recognized the fact that Murchison had the same right to extend the Silurian system to the base of the Llandeilo beds, whatever its horizon, that he had to continue the Cambrian to the top of the Bala beds.*

* One important fact is pointed out in this paper in a letter from M'Coy, on page 143: that the May Hill group, which Murchison had referred to the Caradoc series, really belonged by its fossils to the Upper Silurian. This point was the subject of a paper by Sedgwick in the next volume (vol. ix) of the Journal of the Geological Society.

Murchison's reply was made at the meeting of the Geological Society in June.* He remarked, with regard to Sedgwick's allusion to the excursion of 1834, that "if I lost my way in going downward into the region of my friend, it was under his own guidance; I am answerable only for Silurian and Cambrian rocks described and drawn as such within my own region."

In his closing remarks Murchison says:

"I am now well pleased to find that, with the exception of my old friend, all my geological contemporaries in my own country adhere to the unity of the Silurian System and thus sustain its general adoption."

"No one more regrets than myself that Cambrian should not have proved, what it was formerly supposed to be, more ancient than the Silurian region, and thus have afforded distinct fossils and a separate system; but as things which are synonymous cannot have separate names, there is no doubt that, according to the laws of scientific literature, the term "Silurian" must be sustained as applied to all the *fossiliferous* rocks of North Wales.

"Lastly, let me say to those who do not understand the nature of the social union of the members of the Geological Society, that the controversy which has prevailed between the eloquent Woodwardian Professor and myself has not for a moment interrupted our strong personal friendship. I am indeed confident we shall slide down the hill of life with the same mutual regard which animated us formerly when climbing together many a mountain both at home and abroad."

Murchison was right in saying that all British geologists were then with him, even in the extension of the name Silurian to the lower fossiliferous Cambrian rocks; and this was a chief source of irritation to Sedgwick. It was also, with scarcely an exception, true of geologists elsewhere. This state of opinion was partly a consequence of Murchison's early and wonderfully full description of the Silurian rocks and their fossils, which made his work a key to the Lower Paleozoic of all lands. Sedgwick's Cambrian researches and the paleontology of the region were not published in full before the years 1852–1855, when appeared his "Synopsis of the Classification of the British Palæozoic Rocks," along with M'Coy's "Descriptions of British Palæozoic Fossils."

But this general acceptance was further due to the fact that the discovered fossils of the Cambrian, from the Lingula Flags downward, or the "Primordial," were few, and differed not more from Silurian forms than the Silurian differed among themselves; and also, because the beds were continuous with the Silurian, without a break. Geologists under the weight of

* Q. J. Geol. Soc., viii, 173, 1852.

the evidence, American as well as European, naturally gravitated in the Murchisonian direction, while applauding the work of Sedgwick.

In 1853, Mr. Salter showed, by a study of the fossils,* that the Bala beds from Bala in Merioneth, the original Bala, were included within the period of the Caradoc. Sedgwick subsequently (in the preface to the Catalogue of the Woodwardian Museum by J. W. Salter), divided his Upper Cambrian into (1) The *Lower Bala*, to include the Llandeilo flags (Upper Llandeilo of the Geological Survey, the Arenig being the Lower); (2) the *Middle Bala*, corresponding to the Caradoc sandstone, the Bala rocks, and the Coniston limestone (Geological Survey); and the *Upper Bala* or the Caradoc-shales, Hirnant limestone and the Lower Llandovery."†

In 1854, the Cambrian system not having secured the place claimed for it, Sedgwick brought the subject again before the Geological Society. Besides urging his former arguments, he condemned Murchison's work so far as to imply that none of his sections "give a true notion of the geological place of the groups of Caer Caradoc and Llandeilo"; and to speak of the Llandeilo beds, in a note, as "a remarkable fossiliferous group (about the age of the Bala limestone) of which the geological place was entirely mistaken in the published sections of the Silurian System." There were errors in the sections, and that with regard to the May Hill group was a prominent one; but this was sweeping depreciation without new argument; and, in consequence of it, part of the paper was refused publication by the Geological Society.

The paper appeared in the Philosophical Magazine for 1854.‡ It contains no bitter word, or personal remark against Murchison. Sedgwick was profoundly disappointed on finding, when closing up his long labors, that the Cambrian system had no place in the geology of the day. He did not see this to be the logical consequence of the facts so far as then understood. It was to him the disparagement and rejection of his faithful work; and this deeply moved him, even to estrangement from the author of the successful Silurian system.

CONCLUSION.

The ground about which there was reasonably a disputed claim was that of the Bala of Sedgwick's region and the Llandeilo and Caradoc of Murchison's. Respecting this common field, long priority in the describing and defining of the

* Q. J. Geol. Soc., x, 62.
† Cited from Etheridge, in Phillips' Geology, ii, 77, 1885.
‡ Fourth series, volume viii, pages 301, 359, 481.

Llandeilo and Caradoc beds, both geologically and paleontologically, leaves no question as to Murchison's title. Below this level lie the rocks studied chiefly by Sedgwick; and if a dividing horizon of sufficient geological value had been found to exist, it should have been made the limit between a Cambrian and a Silurian System.

The claim of a worker to affix a name to a series of rocks first studied and defined by him cannot be disputed. But Science may accept, or not, according as the name is, or is not, needed. In the progress of geology, the time finally was reached, when the name Cambrian was believed to be a necessity, and "Cambrian" and "Silurian" derived thence a right to follow one another in the geological record.

"To follow one another;" that is, directly, without a suppression of "Silurian" from the name of the lower subdivision by intruding the term "Ordovician," or any other term. For this is virtually appropriating what is claimed, (though not so intended), and does marked injustice to one of the greatest of British geologists. Moreover, such an intruded term commemorates, with harsh emphasis, misjudgments and their consequences, which are better forgotten. Rather let the two names, standing together as in 1835, recall the fifteen years of friendly labors in Cambria and Siluria and the other earlier years of united research.

ART. XXIII.—*Notes on the Cretaceous of the British Columbian Region.—The Nanaimo Group;* by GEORGE M. DAWSON.

IN Bulletin No. 51 of the United States Geological Survey, (1889) by Dr. C. A. White, on Invertebrate Fossils from the Pacific Coast, Part III is devoted to the discussion of lower Cretaceous fossils from the Vancouver Island region; and the name 'Vancouver group' is proposed for the formation from which these are derived. Dr. White writes:—"Although this formation is paleontologically equivalent, at least in large part, with the Chico portion of the Chico-Téjon series of California, as has been indicated by Meek, Gabb, Whiteaves and by Professor Whitney, I propose to use the name Vancouver group as a local name for those strata which occur in the Vancouver Island region; and still retain the name Chico group for the California strata, which the geologists of that State applied to them."* On meeting with Dr. White's proposal for the adoption of the term 'Vancouver group,' as above stated, I wrote

* Op. cit., p. 33.

to him pointing out that the name had, unfortunately, already been used by me in the publications of the Geological Survey of Canada, to designate the Triassic rocks of the same coast region,* and ventured to suggest that if a local name for the equivalent of the Chico group in the Vancouver Island region is considered requisite, it might be termed the *Nanaimo group*. No general name had, so far as I am aware, been given to the strata in question, previous writers (and more particularly Mr. Whiteaves, by whom a larger proportion of the fossils have been described) thinking it sufficient to refer to them as an extension of the Chico.

Dr. White promptly and cordially replied to my communication, approving of the proposed change of name, and the present note is written primarily at his suggestion in order to prevent possible confusion in the nomenclature.

To more clearly define the strata to which the name Nanaimo group may at present be applied, it is necessary to state that the whole of the large collections examined by Mr. Whiteaves (and doubtless also those of other writers) have been derived from the lower subdivisions of the local section, which, according to the late Mr. James Richardson, is as follows in the Comox and Nanaimo fields respectively:

Comox.	feet.	Nanaimo.	feet.
G. Upper conglomerates	320		
F. Upper shales	776		
E. Middle conglomerates	1,100	G. to C. sandstones Conglomerates and shales	3290
D. *Middle shales*	76		
C. *Lower conglomerates*	900		
B. *Lower shales*	1,000	B. *Shales*	660
A. *Productive Coal-measures*	739	A. *Productive Coal-measures*	1360

As stated by Mr. Whiteaves, no characteristic fossils have yet been found in the three higher subdivisions of the Comox section (E., F. and G.) nor in subdivisions C. to G. inclusive of the Nanaimo section,† and while all the subdivisions are conformable, it is thus the lower parts of the sections alone, including about 2,020 feet at Nanaimo and 2,715 feet at Comox, which are known to correspond more or less perfectly with the Chico group. These are printed in italics in the above table. In the publication just alluded to, Mr. Whiteaves further states, that there was, at the time he wrote, no positive evidence to show whether the upper portions of these sections were Cretaceous or Tertiary, and this statement still holds good. It is therefore quite possible that some at least of the higher subdivisions may represent the Téjon group of Califor-

* See particularly Annual Report Geol. Survey, Can., 1886, p. 10 B.
† Mesozoic Fossils, vol. i, pp. 94, 185.

nia, or the recently proposed Puget group of Washington,* both of which Dr. White is inclined to regard as equivalent in a general way to the Laramie.†

While referring to the Puget group, it may be added that a considerable tract of low land about the mouth of the Fraser and extending northward to Burrard Inlet, is underlain by rocks which though as yet only partially examined, appear with little doubt to correspond to that group, with which they are geographically connected and so far as known lithologically identical. Mr. A. Bowman has ascertained that these strata are at least 3000 feet in thickness, and, like those of the typical area of the Puget group, they hold carbonaceous matter and more or less lignite-coal at many different horizons.

I may also take the opportunity to note, in this connection, that throughout the entire Cretaceous period as represented on the littoral of British Columbia, there is evidence of a transgressive extension of the area of sedimentation from north to south, the local base of the Cretaceous being found at successively higher stages in the system to the southward. Thus, of five stages into which the Cretaceous of the Queen Charlotte Islands is divided, the three highest only have been found resting on the pre-Cretaceous rocks of the northern part of Vancouver Island. In the Comox and Nanaimo fields, the local base of the Cretaceous corresponds approximately to the highest observed beds of the first-mentioned locality, and in northern Washington, the still higher Puget group occurs in very great mass and apparently almost to the exclusion of the Cretaceous proper, or marine Cretaceous as distinguished from the Laramie. Though further investigation may disclose small areas of older Cretaceous rocks, occupying the deeper hollows in the much-eroded surface of the pre-Cretaceous land, these can scarcely be such as to invalidate the general features as now understood and above outlined. Coupled with this gradual southward encroachment of the Cretaceous Sea, is no doubt the fact that the principal coal-bearing horizon, beginning at the north in the earlier Cretaceous (about the horizon of the Gault) is found at Comox and Nanaimo near the base of the Nanaimo group (representing the Chico) and in Puget Sound in the Puget group, which as already noted may, according to Prof. Newberry and Dr. White, be equivalent to the Laramie.

We have yet, however, much to learn respecting the physical history of the Cretaceous period in the British Columbian region; and in view of the above facts relating to the littoral of the Province, it remains in particular to explain the occur-

* This Jour., vol. xxxvi, 1888.

† Bulletin of the U. S. Geol. Survey, No. 51, pp. 12, 54.

rence of the earlier Cretaceous rocks which at no great distance inland run parallel to the basin occupied by the Nanaimo and Puget groups.* It appears possible that an elevation of a part of the Cretaceous sea-bed bounded to the westward nearly by the present line of the Coast Ranges of British Columbia, may have occurred after the deposition of the earlier strata. The tract of land thus produced, or added to that previouly in existence, may have served as the chief source of supply of the later sediments and more particularly of the massive estuarine beds of the Puget group, in accounting for which Dr. White finds some difficulty.† Such a supposition would also be in accord with the absence, so far as known, of any rocks referable to the Laramie throughout the entire region eastward to the Rocky Mountains proper, within the limits of British Columbia.

Geological Survey of Canada, Ottawa, Dec. 18, 1889.

Art. XXIV.—*Celestite from Mineral County, West Virginia;* by George H. Williams.

An extensive cutting on the line of the West Virginia Central railroad has recently brought to light a large number of celestite crystals, which, on account of their unusual habit, large size and fine color, merit description. The cutting is nearly a mile in length and had been made into a high bluff of lower Helderberg limestone which forms the western flank of Knobly mountain, between the fourth and fifth milestones south of Cumberland, Md. The crystals thus far discovered occur just outside the limits of the State of Maryland, since the Potomac river here flows so near the base of the mountain that sufficient space for the railroad had to be secured by artificial means between them.

The writer is indebted to the kindness of Mr. F. M. Offutt of Cumberland for first bringing the crystals to his notice; as well as to the efforts of Mr. J. C. Brady (on whose farm the crystals occur) and his sons for aid in securing most of the material that has thus far come to light.

The rock exposed in the cutting is a thickly bedded and nearly horizontal, argillaceous limestone, similar to that used at Cumberland and Hancock, Md., for the manufacture of cement. The crystals occur in flattened lenticular cavities or pockets, which vary from a foot to a yard in diameter and from three to seven inches in height. These are confined to only two or three of the many strata which compose the bluff and apparently

* Cf. this Jour., vol. xxxviii, p. 121.

† Bulletin of the U. S. Geol. Survey, No. 51, p. 57.

represent former concretions. They are now partially empty and partially filled with clay. The celestite crystals adhere to the walls of these cavities or lie unattached in the clay. The latter are the most perfectly developed, being in most cases doubly terminated, and occurring either singly or in groups. With the celestite, minutely crystalline calcite is associated, exhibiting the combination: ∞P $(10\bar{1}0)$ and $-\frac{1}{2}R$ $(01\bar{1}2)$. No other mineral was observed within these ovoid cavities except gypsum, minute crystals of which sometimes incrust the celestite crystals, especially near their acute ends.

The celestite crystals vary in length from less than a millimeter to three inches or more. The largest are two inches in thickness. In color they range from a deep blue to the palest possible tint. Some are even colorless. One specimen shows layers parallel to the macropinacoid which are alternately of a lighter and darker color. Many of the smallest or medium-sized crystals are clear and transparent, but the large majority are more or less opaque from internal impurities. The clay, in which the crystals appear to have grown, is frequently included in them in large amount.

The most striking feature presented by this occurrence of celestite is, however, its crystal-habit. This is pyramidal, which is not common for the species, and is always due to the preponderance of the acute brachy-pyramid χ, $P\frac{4}{3}$ (144). On a large proportion of the crystals, especially the smaller ones, this form occurs alone, when it becomes almost lenticular from a rounding of the faces (fig. 6). On other crystals other forms were observed in combination with the above-named pyramid. These are, in order of their frequency and importance, as follows: *a*, $\infty P\infty$ (100); *d*, $\frac{1}{2}P\infty$ (102); *c*, OP (001); *o*, $P\breve{\infty}$ (011); and *m*, ∞P (110) (figs. 1 and 2). Of these forms, *d* is the only one whose planes are sufficiently even and bright to yield satisfactory measurements. *a* is always striated parallel to the vertical axis, probably by oscillatory combination with *m*. *c*, the principal cleavage plane, is uneven and drusy, when it occurs at all. *o* is usually present only as a rounding of the edge: $(144):(\bar{1}44)$, but in a few cases yielded a tolerably sharp reflex. *m* is of extremely rare occurrence and even then is so poorly developed as to leave its identification doubtful.

The following angles, obtained with a reflecting goniometer are unsatisfactory, owing to the uneven nature of all the planes except *d*. They are compared with the calculated angles given by Auerbach in his monograph on celestite,* because none of the data requisite to the calculation of a new axial-ratio could be obtained.

* Sitzungsberichte der Wiener Akad., vol. lix, p. 549. 1869.

		(Observed.)	(Auerbach.)
$o \wedge o$	$(011):(0\bar{1}1)$	103° 33′	104° 8′ 14″
$d \wedge d$	$(102):(10\bar{2})$	101° 26′	101° 11′
$d \wedge c$	$(102):(001)$	139° 57′	140° 35′ 30″
$\chi \wedge o$	$(144):(011)$	166° 50′—165° 12′	165° 47′ 44″
$\chi \wedge \chi$	$(144):(\bar{1}44)$	150° 20′—153° 10′	151° 35′ 28″

The variations in the angles measured against the face χ are due to its extremely rounded character and to the flatly convex prominences with which it is invariably covered (figs. 8, 9, 10 and 11). Quite as reliable measurements were made on the largest crystals with a hand goniometer, which gave for the angle $(144):(\bar{1}44)$ values between $150\frac{1}{2}°$ and $152\frac{1}{2}°$, with an average closely approaching $151\frac{1}{2}°$. This is sufficient to fix the symbol of the predominating form, since the corresponding angle for the pyramid $P\frac{5}{5}$ (155) is 157° 7′; and for $P^{\frac{5}{3}}$ (133), 142° 47′.

The irregularities of growth which have interfered with the evenness of the planes on the celestite crystals, do not appear to have materially affected their internal homogeneity. This was shown by an optical examination. A section cut parallel to the macropinacoid, a, showed a normal interference figure in converged polarized light, by means of which the optical angle was measured in a Thoulet solution of specific gravity, 2·922.

This gave for lithium light, $2H_a = 49° 04′$,
and for sodium light, $2H_a = 49° 28′$.

From Goldschmidt's curve* the index of refraction for this solution was found to be for lithium light 1·666, and for sodium light 1·675; and, assuming the mean index of refraction of celestite, β, to be for lithium light 1·621, and for sodium light 1·624,† we obtain as the true optical angle:

Li	$2V_a = 49° 18′$
Na	$2V_a = 49° 54′$

The celestite crystals were subjected to a chemical examination by Mr. W. F. Hillebrand of the U. S. Geological Survey, who reports that they are composed of strontian sulphate, in which he was able to detect only a faint (spectroscopic) trace of BaO and 0·12 per cent of CaO. The adjacent limestone was also tested for strontian which was found so abundantly in the form of the sulphate as to indicate that the rock was strongly impregnated with celestite substance for some distance.

Celestite crystals of a pyramidal habit are not common, but they have, nevertheless, been described from several localities.

* Neues Jahrbuch für Min., etc. Beil. Bd. i, Pl. vii. 1881.

† Cf. Arzruni: Zeitschr. für Kryst., vol. i, p. 179. 1877. Babcock: Neues Jahrbuch für Min., etc., 1879, p. 838.

In nearly all cases the predominating form is the brachypyramid, φ, $P\breve{3}$ (133). Such, for instance, are the crystals called by Haüy "apotome" from the marl of Montmatre and Bougival near Paris;* and those designated as "dioxynite" from Meudon in the same region.† Similar crystals of celestite are also described by Sucrow‡ and Schmid§ from the Muschelkalk of Dornburg near Jena; by von Lasaulx from Girghenti on Sicily;‖ and by Groth from Hall in the Tyrol.¶

The brachypyramid, χ, $P\breve{4}$ (144) was first mentioned by Brooke and Miller.** It has since been recognized by Auerbach on crystals from Dornburg, and Montecchio in Vicentia;†† by Groth on those from Pschow in Silesia;‡‡ and by von Hauer on those from the Banat.§§

This pyramid was, however, first noticed as predominating and giving the habit to celestite crystals by von Lasaulx in 1879.‖‖ This author describes an occurrence of this mineral in the marl of Ville-sur-Saulx, Dept. Haute Marne, France, which must bear a close resemblance to that in Mineral Co., W. Va. At least this would appear to be the case from the published descriptions, since I have had no opportunity to examine specimens from this locality.

In passing, it may also be not without interest to refer to the pyramidal crystals of Hungarian anglesite figured by Krenner.¶¶ These often have a habit closely like that of the above-mentioned celestites, but their predominating pyramid is π, $P\breve{5}$ (155).

The West Virginia celestite crystals acquire additional interest from their strong resemblance, in form as well as in their surface markings, to the well-known Sangerhausen pseudomorphs, whose further resemblance to the "thinolite" of the desiccated lake-basins of the west has been pointed out by Clarence King, and E. S. Dana.*** The Sangerhausen pseudomorphs have generally been referred to gaylussite, but Descloizeaux unqualifiedly identifies them with the variety of celestite

* Traité de Minéralogie, 2d ed., 1882, vol. ii, p. 33. Atlas, Pl. xliii, fig. 81.

† Ibid., p. 35. Atlas, pl. xliv, fig. 85. Cf. Schrauf's Atlas der Krystalformen, V Lieferung, 1876.

‡ Pogg. Ann., vol. xxix, p. 504, pl. i, fig. 16, 1833

§ Ibid., vol. cxx, p. 637. 1863.

‖ Neues Jahrbuch für Min., etc., 1879, p. 509.

¶ Mineraliensammlung der Universität Strassburg, 1878, p. 146.

** Mineralogy, 1852, p. 527.

†† Sitzungb. Wien. Akad, vol. lix, pp. 580 and 588. 1869.

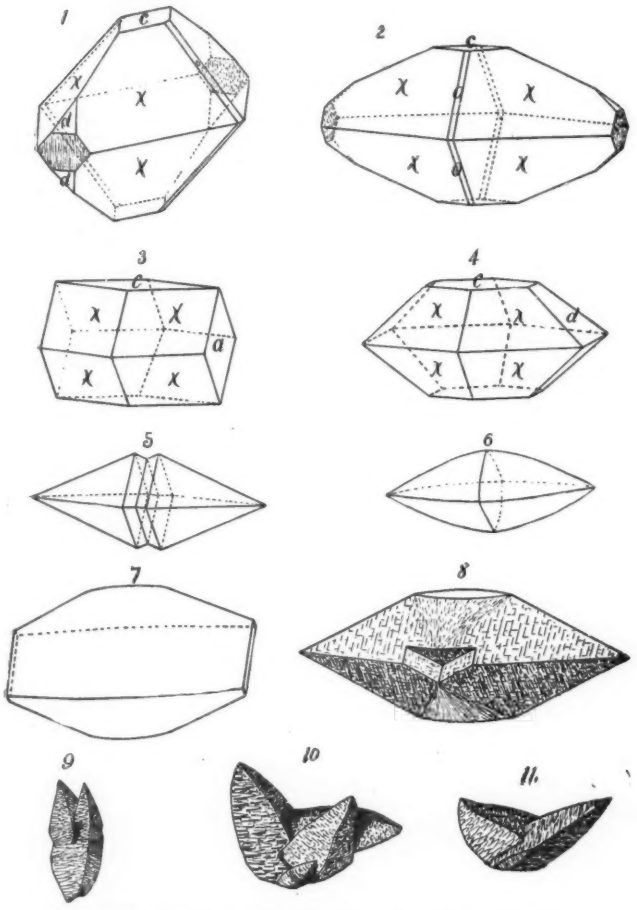
‡‡ Mineraliensammlung der Universität Strassburg, 1878. p. 146.

§§ Verhandl. k.k. geol. Reichsanstalt, 1879, p. 216. Cf. Zeitschr. für Kryst., vol. iv, p. 634.

‖‖ Sitzungsber. der schlesischen Gesellschaft für vaterlandische Cultur, Nov. 19, 1879. Cf. Zeitschr. für Kryst, vol vi, p. 203.

¶¶ Zeitschr. für Kryst., vol. i, pl. xv, 1877.

*** A Crystallographic Study of the Thinolite of Lake Lahontan. Bull. U. S. Geol. Survey, No. 12, 1884.



CELESTITE CRYSTALS FROM MINERAL CO., WEST VIRGINIA.

FIG. 1.—Combination showing the forms χ, $P\frac{1}{4}$ (144); a, $\infty P\bar{\infty}$ (100); c, $0P$ (001); d, $\frac{1}{2}P\infty$ (102); o, $P\bar{\infty}$ (011). Miller's position.

FIG. 2.—Same, turned 90° about the vertical axis into the position assumed by von Lang for anglesite. This is so much more advantageous for showing the forms of these crystals that it is retained in all the other figures.

FIG. 3.—Exceptional combination of χ, a and c.

FIG. 4.—Ditto of χ, c and d.

FIG. 5.—Parallel growth of two individuals.

FIG. 6.—Crystal showing only the form χ, which is almost lenticular from the curvature of its planes.

FIG. 7.—Distorted form, with χ, a, and a rounded surface corresponding to o.

FIG. 8.—Crystal bounded by χ and c, with a conically rounded surface in place of o.

FIGS. 9, 10 and 11.—Crystal groups showing growth forms and surface markings.

called by Haüy "apotome."* The striking likeness between the forms of the West Virginia celestite and the Sangerhausen pseudomorphs may be seen by comparing the last three of the preceding figures with those numbered 26, 31 and 32 in Professor Dana's paper. This will at least serve to show the resemblance which must exist between the products of the locality here described and those mentioned by Haüy near Paris, where, he says, the celestite also occurs in "flattened ovoid masses."†

ART. XXV.—*A Method for the Determination of Iodine in Haloid Salts;* by F. A. GOOCH and P. E. BROWNING.

(Contributions from the Kent Chemical Laboratory of Yale College.—I.)

FEW problems of analysis have been more discussed than the estimation of iodine accompanying chlorine and bromine in haloid salts; and yet the constant succession of new processes is sufficiently indicative that the solution of the question is not generally regarded as satisfactorily settled. The method of Fresenius, according to which iodine is liberated by nitrous acid, collected in carbon disulphide and titrated by sodium thiosulphate, finds ready acceptance for the determination of small amounts of iodine; but when the quantity of iodine to be estimated is considerable, the method is unwieldy. Probably the process most generally in use is that based upon the liberation of iodine by means of a ferric salt, and the titration of the distillate by one or other of the well-known iodometric methods. The latter method is fairly accurate, but the requirement of special apparatus for properly condensing the distillate is detrimental to rapidity and ease of execution. In this process the amount of iodine set free should be measured exactly by the reduction of the ferric salt, and were the ferrous salt produced in the course of the action sufficiently stable, the determination of its amount might be substituted for the titration of the iodine, and so the collection and further treatment of the distillate might be dispensed with; but ferrous salts are too sensitive to atmospheric influence to preserve under the conditions of this process their own degree of oxidation, and the amount of iron found in the ferrous condition cannot be made to serve as a trustworthy indication of the reducing action which actually takes place in the separation of the iodine. The advantage of replacing the collection and ex-

* Ann. chim. et phys. III, vol. vii, p. 489, 1843; Manuel de Minéralogie, vol. ii, p. 119, 1874.

† Traité, 2d ed., vol. ii, p. 37, 1822.

amination of the distillate by treatment of the residue is, however, so great as to constrain us to search for some substitute for the ferric salt, which, by virtue of easy reducibility may act as a liberator of iodine from hydriodic acid, and, at the same time, by reason of stability after reduction, shall register accurately the quantity of iodine set free in the reducing process. The results of our experience are contained in the following account.

Strong sulphuric acid, as is well known, acts upon an iodide in a way to liberate iodine at the cost of its own loss of oxygen, though by simple dilution of the mixture thus formed the action is reversed, the iodine going back into the form of hydriodic acid, and the products of the reduction of sulphuric acid again taking back their oxygen and re-forming the acid. In the presence of any substance easily reducible by the deoxidation products of sulphuric acid the liberation of iodine, by the action of that acid upon iodides, should take place without interference, and even more easily and completely than in the absence of such a substance, while the sulphuric acid should remain at the end of the process in its original form. If the products of reduction which appear in such a case in the place of those of the sulphuric acid should be neither readily oxidizable nor easily volatilizable, it ought to be possible to remove by heat the iodine set free in the action without disturbing the record kept of its amount by the reduced substance remaining in the residue.

The qualities of arsenic acid suggest it as a substance likely to possess just these qualities; for, though arsenious acid is converted into arsenic acid by the action of iodine in alkaline solution, in acid solution the reverse is true to at least a limited extent, and arsenic acid liberates iodine according to the equation,

$$H_3AsO_4 + 2HI = H_3AsO_3 + H_2O + I\text{-}I.$$

In company with sulphuric acid of such strength as to liberate the iodine from hydriodic acid, the reduction should fall in the end upon the arsenic, and the arsenious oxide produced should, under proper conditions, preserve the record of the iodine liberated and removed by volatilization. We therefore undertook experimentation upon this line, and the accompanying table shows the results of a preliminary investigation of the mode of action of a mixture of sulphuric and arsenic acids upon an alkaline iodide. In making these tests a standard solution of potassium iodide was put into a test-tube, a solution of potassium arseniate was added, sulphuric acid mixed with its own volume of water was introduced, the volume of the liquid was adjusted, a film of kerosene 3 mm. thick was placed upon the surface of the liquid, and the whole was heated gently and agi-

tated. Kerosene was chosen in preference to other solvents of iodine on account of its lightness, which makes it float upon the mixture, and its high boiling-point, which permits the application of heat to hasten and complete the reaction. Its disadvantage is the persistency with which it adheres to the walls of the test-tube, so that washing with alcohol (or other solvent) after the completion of each test is necessary to prevent the transfer of the iodine of one test to the test next succeeding. The data of these experiments are indicated in the headings.

It will be noted that in Series A, in which the absolute amount of iodine employed, its proportion to the entire volume, and the amount of the arsenic salt remained the same, the proportion of sulphuric acid being the variable element, it is shown that the proportion of sulphuric acid should reach at least twelve parts by volume in one hundred of the solution in order that the maximum distinctness of the test may be developed. An excess of sulphuric acid beyond this proportion is not disadvantageous.

In Series B the proportion and absolute amount of iodine vary as well as the proportion of acid, while the quantity of arsenic remains invariable. The results of this series confirm those of the previous series as to the proper proportion of sulphuric acid to be used, and the sensitiveness of the test is shown to reach (in round numbers) one part by weight of iodine in six hundred thousand parts of the solution.

The tests of Series C indicate plainly that it is the sulphuric acid which is the potent agent in liberating the iodine, the experiment in which acetic acid was substituted for sulphuric acid being particularly noteworthy in this connection. The presence of arsenic acid increases the sensitiveness of the reaction, but its addition beyond a very moderate amount does not appear to be necessary or advantageous. The presence of a chloride or bromide does not impair the delicacy of the test.

The quantities of iodine taken in the experiments just described were necessarily small, and the question arises naturally as to whether the course of action would be similar in the presence of larger amounts of that substance and the correspondingly greater amount of arsenious oxide which is produced with its tendency to reverse the reaction according to which the elimination of iodine proceeds. The solution of this question was reached in the following experiments:

To 50 cm^3 of liquid containing 10 cm^3 of sulphuric acid [1 : 1], and 1 cm^3 of a decinormal solution of iodine in potassium iodide (0·001265 grm. of the former in 0·0018 grm. of the latter) was added 1 cm^3 of a decinormal solution of arsenious oxide (0·00495 grm.), an amount ten times as much as would be necessary to convert the iodine into hydriodic acid were

the solution alkaline. The color of the iodine vanished gradually under the action of the arsenious acid, but was restored by the addition of 1 grm. of hydrogen potassium arseniate, and again dispelled by another portion of arsenious acid equal in amount to that introduced at first. Heat was applied at this

SERIES A.

KI.	Grms. of Iodine to cm^3 of solution.	H_3KAsO_4	H_2SO_4. [1 : 1]	H_2SO_4 (strong) in 100 parts by volume.	NaCl.	KBr.	Total vol.	Reaction for Iodine.
grm.		grm.	cm^3		grm.	grm.	cm^3	
0·0001	1 : 132000	1	2	10 : 100	----	----	10	Faint.
0·0001	1 : 132000	1	2	10 : 100	----	----	10	Faint.
0·0001	1 : 132000	1	2·5	12·5 : 100	----	----	10	Faint.
0·0001	1 : 132000	1	2·5	12·5 : 100	----	----	10	Distinct.
0·0001	1 : 132000	1	3	15 : 100	----	----	10	Distinct.
0·0001	1 : 132000	1	4	20 : 100	----	----	10	Distinct.
0·0001	1 : 132000	1	4·5	22·5 : 100	----	----	10	Distinct.
0·0001	1 : 132000	1	5	25 : 100	----	1	10	Distinct.

SERIES B.

0·0005	1 : 26400	1	2·5	12·5 : 100	----	----	10	Distinct.
0·000133	1 : 99000	1	2·5	12·5 : 100	----	----	10	Distinct.
0·0001	1 : 198000	1	3	10 : 100	0·007	----	15	Faint.
0·000067	1 : 198000	1	2·5	12·5 : 100	----	----	10	Faint.
0·000067	1 : 198000	1	2·5	12·5 : 100	----	1	10	Faint.
0·0001	1 : 198000	1	5	16·6 : 100	0·005	----	15	Distinct.
0·0001	1 : 198000	1	5	16·6 : 100	0·005	----	15	Distinct.
0·0001	1 : 264000	1	2 5	6·25 : 100	----	----	20	Invisible.
0·0001	1 : 264000	1	2·5	6·25 : 100	----	----	20	Faint.
0·0001	1 : 264000	1	5	12·5 : 100	----	----	20	Faint.
0·000033	1 : 396000	1	2·5	12·5 : 100	----	----	10	Faint.
0·000033	1 : 396000	1	2·5	12·5 : 100	----	----	10	Faint.
0·000033	1 : 594000	1	5	16·6 : 100	0 005	----	15	Faint.

SERIES C.

0·0020	1 : 8000	1	None. Acetic acid 1·5 grm. (absolute).	----	----	----	12	Invisible.
0·0010	1 : 13200	----	5 cm^3	25 : 100	----	----	10	Distinct.
0·0002	1 : 66000	----	5	25 : 100	----	----	10	Faint.
0·0010	1 : 13200	0·2	5	25 : 100	----	----	10	Marked.
0·0001	1 : 132000	0·2	5	25 : 100	----	----	10	Distinct.
0·000033	1 : 198000	0·5	1 25	12·5 : 100	----	----	5	Faint.
0·000033	1 : 198000	0·5	1·25	12 5 : 100	----	----	5	Faint.
0·0001	1 : 264000	2 0	4	10 : 100	----	----	20	Faint.
0·0001	1 : 264000	2 0	6	15 : 100	----	----	20	Faint.

point with the result that the color of iodine showed again faintly, and upon boiling the liquid until its volume decreased to 25 cm^3 it became colorless and yielded no iodine when agitated with nitrous acid and chloroform.

An experiment differing from the last in that thirty times as much arsenious oxide and iodine were taken, gave similar results.

It is plain, therefore, that the arsenious acid and arsenic acid exert opposite effects under the conditions of these experiments, and that one or the other prevails according to the proportionate composition of the solution, the degree of dilution, and the temperature.

The experiments detailed in the following statement were intended to determine the conditions best adapted to eliminate the iodine from such quantities of potassium iodide as would ordinarily be dealt with in the course of analysis.

A solution of potassium iodide was placed in an Erlenmeyer beaker of 300 cm^3 capacity, followed by a solution of potassium arseniate and by dilute sulphuric acid [1 : 1], and the volume of the liquid was diluted to about 100 cm^3. A mark was put upon the beaker to indicate the level to which the liquid was to be reduced, a spiral of platinum wire was placed in the solution to prevent explosive ebullition, and the contents of the flask were boiled until the desired degree of condensation was reached. Colorlessness of the liquid at this point, though a fair indication of the absence of free iodine, is no indication that the hydriodic acid has been completely decomposed, and so, in the event of finding the liquid colorless, it was first cooled and shaken with chloroform to prove or disprove the absence of free iodine, and then tested for the presence of hydriodic acid by shaking with nitrous acid and chloroform.

An inspection of these results shows at once that when the larger amounts of iodine are to be eliminated the proportion of sulphuric acid to the final volume after boiling needs to be increased somewhat beyond that which is necessary to set free very small portions such as were dealt with in the experiments of the earlier series.

In Series D it appears that the proportion of sulphuric acid increases from 8·3 per cent to 25 per cent of the whole volume before the liquid is found to be free from iodine as such, and even then there sometimes remain minute, though probably insignificant traces of hydriodic acid.

In the experiment of Series E the liquid was diluted after concentration and the boiling repeated, and the volatilization of the iodine was thus more nearly perfected than in the corresponding experiments of the previous series—a proportion amounting to 16·6 per cent apparently accomplishing the work done by 25 per cent of the same acid in a single concentration. The results of Series F, G, and H, are closely comparable with those of the corresponding experiments of Series D. Throughout these experiments it is again made evident that it is the proportion,

and not the absolute amount, of sulphuric acid which is the great factor in the liberation of the iodine. So far as concerns the purposes of good analysis these results indicate the elimina-

SERIES D.

KI.	H_2SO_4 [1:1].	Per cent of strong H_2SO_4 by volume.	H_2KAsO_4.	Final volume.	Free Iodine.	Combined Iodine.
0·5 grm.	10 cm³	8·3	1 grm.	60 cm³	Present	Abundant.
0·5	10	10	1	50	Present	Abundant.
0·5	10	12·5	2	40	Present	Distinct.
0·5	10	12·5	2	40	Trace	Distinct.
0·5	10	12·5	4	40	Trace	Distinct.
0·5	10	16·6	1	30	Trace	--------
0·5	10	16·6	2	30	Trace	--------
0·5	10	16·6	2	30	Trace	--------
0·5	10	16·6	4	30	None	Distinct.
0·5	10	16 6	5	30	Trace	Distinct.
0·5	10	25	1	20	None	Faintest trace.
0·5	10	25	2	20	None	Faintest trace.
0·5	10	25	2	20	None	Faintest trace.
0·5	10	25	2	20	None	Faintest trace.
0·5	10	25	2	20	None	Faintest trace.

SERIES E.

0·5 grm.	10 cm³	16·6	1 grm.	30 cm³ 30	None	Faintest trace.
0·5	10	16·6	1	30 30	None	Faintest trace.
0·5	10	16·6	1	30 30	None	Faintest trace.
0·5	10	16·6	1	30 30	None	Faintest trace.

SERIES F.

0·5 grm.	15 cm³	25	2 grm.	30 cm³	None	Faintest trace.
0·5	15	25	2	30	None	Faintest trace.
0·5	15	25	4	30	None	Faintest trace.

SERIES G.

0·5 grm.	20 cm³	25	2 grm.	40 cm³	None	Faintest trace.
0·5	20	25	2	40	None	Faintest trace.
0·5	20	25	2	40	None	None.
0·5	20	28·6	2	35	None	None.
0·5	20	28·6	2	35	None	None.
0·5	20	33·3	2	30	None	None.

SERIES H.

0·5 grm.	30 cm³	25	2 grm.	60 cm³	None	Faintest trace.
0·5	30	25	2	60	None	Faintest trace.

tion of iodine to a reasonable sufficiency when the reduction of bulk raises the percentage by volume of the strong sulphuric acid to twenty-five, and to perfection, as in the latter deter-

minations of Series G, when the percentage reaches twenty-eight and a half. It remains to be seen whether the arsenious oxide reduced in the separation of the iodine will resist successfully, under the conditions of these experiments, the tendency to volatilize which the presence of chlorides and bromides, and the consequent liberation of hydrochloric and hydrobromic acids, might presumably induce.

The experiments of Series I were directed to the elucidation of this point.

Decinormal solutions of iodine and arsenious acid prepared, standardized, and tested against one another in the usual manner. Definite portions of the solution of arsenious acid were measured from a burette into Erlenmeyer beakers such as were used in the previous experiments, sulphuric acid [1 : 1], and sodium chloride were added, the volume of the liquid was adjusted to 100 cm^3, or a little more, and the process of concentration by boiling was carried to the point desired and indicated by a mark upon the flask. After cooling, the acid was neutralized and the titration effected in the usual manner in the presence of an excess of acid potassium carbonate and starch employed as the indicator. These experiments were arranged upon the presumption that the essential conditions determining the degree of volatility of the arsenic when the reduction is effected by hydriodic acid are imitated, though neither hydriodic acid, nor arsenic acid, nor free iodine is present.

SERIES I.

H_2SO_4 [1:1].	NaCl.	Final volume.	Per cent of strong H_2SO_4 by volume.	As_2O_3 taken.	As_2O_3 found.	Loss.
10 cm^3	1 grm.	20 cm^3	25	0·0495 gr.	0 0485 gr.	0·0010 gr. —
10	1	20	25	0·0495	0·0493	0 0002 —
10	1	20	25	0·0495	0·0488	0·0007 —
10	0·8	20	25	0·0495	0·0488	0·0007 —
10	0·5	20	25	0·0405	0·0495	0·0000
20	1	40	25	0 0495	0·0490	0·0005 —
20	1	40	25	0·0495	0·0490	0·0005 —
20	0·8	40	25	0 0495	0·0490	0·0005 —
20	0·5	40	25	0·0495	0·0490	0.0005 —
20	0·5	40	25	0·1385	0·1380	0·0005 —
20	1	30	33·3	0·0495	0·0476	0·0019 —
20	0·8	30	33·3	0·0495	0·0466	0·0029 —
20	0·5	30	33·3	0·0495	0·0481	0·0014 —
20	0·5	30	33·3	0·0495	0·0485	0 0010 —
20	0·5	30	33·3	0·0595	0·0490	0·0005 —
20	0·5	30	33·3	0 0495	0·0490	0·0005 —
20	0·5	30	33·3	0·0495	0·0490	0·0005 —
30	1	60	25	0·0495	0 0485	0·0010 —
30	0·8	60	25	0·0495	0 0490	0 0005 —
30	0·8	60	25	0·0495	0 0490	0 0005 —
30	0·5	60	25	0·0495	0·0490	0·0005 —

SUMMARY OF SERIES I.

H_2SO_4 [1:1].	Final volume.	Per cent of strong H_2SO_4 by volume.	NaCl.	Mean loss of As_2O_3.	Number of determination.
10 cm³	20 cm³	25	1 grm.	0·0006 gr—	3
20	40			0·0005 —	2
30	60			0·0010 —	1
10	20	25	0·5 and 0·8	0·0003 —	2
20	40			0·0005 —	3
30	60			0·0005 —	3
20	30	33·3	0·5	0 0008 —	5
			0·8	0·0019 —	1
			1·0	0·0029 —	1

It appears in these results that there is some loss of arsenic in nearly every case within the limits of our experimentation, the amount of volatilization increasing with the ratio of sulphuric acid to the entire volume when the quantity of chloride present is constant, and likewise with the amount of chloride when the ratio of the acid to the total liquid is constant.

The effect of increasing the amount of chloride is naturally accounted for by the "mass action" of the hydrochloric acid thus liberated upon the arsenious oxide in solution; that it is the proportion, and not the absolute amount, of sulphuric acid which determines the degree of volatility of the arsenic is explicable upon the assumption that the smallest quantity of sulphuric acid employed is sufficient to liberate all the hydrochloric acid (or, at least, nearly all), and that this, by its action on the arsenious oxide, forms the volatile chloride proportionately to the amount of water removed bodily by concentration or withheld from effective action by the attraction of the sulphuric acid.

In extending this line of experimentation to cases involving the action of hydrobromic acid upon arsenious oxide we found it sufficient for our purpose to employ only the highest degree of concentration recorded in the previous experiments and to use 1 grm. of potassium bromide—an amount corresponding, molecule for molecule, to about 0·5 grm. of sodium chloride. The results, given in Series J, indicate that under these circumstances the loss of arsenic is inappreciable.

SERIES J.

H_2SO_4 [1:1].	KBr.	Final volume.	Per cent of strong Hs_2SO_4 by volume.	As_2O_3 taken.	As_2O_3 found.	Loss.	Mean loss.
	grm.			grm.	grm.	grm.	grm.
20 cm³	1	30 cm³	33·3	0·0495	0·0490	0·0005	
20	1	30	33·3	0·0495	0·0493	0·0002	
20	1	30	33·3	0·0495	0·0495	0·0000	0·0001—
20	1	30	33·3	0·0495	0·0495	0·0000	
20	1	30	33·3	0 0495	0 0495	0·0000	

It appears, therefore, from the results of Series I, that, when the amount of sodium chloride present is restricted to 0·5 grm., the liquid may be boiled until the sulphuric acid amounts to 33·3 per cent of it, with a loss, on the average, of 0·0008 grm. of arsenious oxide, and to 25 per cent with a loss of 0·0004 grm. With either of these proportions the results are sufficiently favorable to warrant quantitative testing of a method for separating chlorine and iodine based upon the volatility of iodine and the non-volatility of arsenious oxide under the conditions. The case is even more favorable for the similar separation of bromine from iodine—the loss of arsenic amounting on the average to 0·0001 grm., under similar conditions. The experiments of Series D to H indicated that the degree of concentration at which all iodine vanishes from the liquid corresponds to the presence of 28·6 per cent of the acid—a point midway between the points of concentration indicated above. We fixed this proportion, therefore, for the following experiments, as being rather more favorable as regards the fixity of the arsenic and perfect as to the elimination of iodine. The smallest absolute amount of sulphuric acid which we have used—10 cm^3 of the [1 : 1] mixture—demands evaporation of the liquid to a bulk too small to be easily determined with certainty in flasks of the shape and dimensions which we found convenient for this work. The larger amounts of acid are uncomfortably large in the subsequent neutralization. We took, therefore, 20 cm^3 of the [1 : 1] mixture of sulphuric acid and water as the amount best adapted to our purpose and set the limit of concentration at 35 cm^3.

The potassium iodide which we used was prepared with great care, by acting with re-sublimed iodine upon iron wire, three-fourths of the iodine being added to an excess of iron covered with distilled water, decanting the solution from the excess of iron when the color of iodine had vanished, adding the remainder of the iodine, pouring the filtered solution slowly into boiling water, to which the exact amount of acid potassium carbonate necessary to combine with the iodine had been added, and filtering off the magnetic oxide of iron thus precipitated. The solution of potassium iodide thus made, very faintly alkaline and entirely free from chlorine and bromine, was made up to a suitable volume and standardized by precipitating the iodine of aliquot portions by weight as silver iodide, which was heated and weighed upon asbestos. Weighed portions of this solution, containing approximately 0·5 gm. of potassium iodide to 30 cm^3, were taken for the tests in which the larger quantities of iodine were introduced; measured portions of a solution made by diluting the former were employed in the tests involving the smaller amounts.

The sodium chloride and potassium bromide used were shown to be free from iodine, and the hydrogen potassium arseniate contained no arsenious acid.

The mode of proceeding was, in general, like that of the previous experiments. The solution of potassium iodide was put in an Erlenmeyer beaker of 300 cm^3 capacity, two grams of hydrogen potassium arseniate were added in solution and followed by 20 cm^3 of sulphuric acid [1 : 1], the liquid was diluted with water to a little more than 100 cm^3, a platinum spiral was placed in the flask to secure quiet ebullition, a trap made by cutting off a two-bulb drying tube about an inch from the inside bulb was hung, large end downward, in the mouth of the flask to prevent mechanical loss, and the liquid was boiled until the level reached the 35 cm^3 mark put upon the flask. At this point the flask was cooled, the acid nearly neutralized with sodium hydrate in solution, the neutralization completed by acid potassium carbonate, 20 cm^3 of the last being added in excess, a definite portion of starch indicator added, and the contents in arsenious acid determined by titration with a decinormal solution of iodine for the larger amounts, and a centinormal solution for the smaller. Due correction was made for the amount of iodine necessary to develop the test-color in a solution prepared and treated similarly in all respects to the experimental solutions excepting the introduction of the iodide—the correction amounting to a single drop more of the decinormal solution than was required to produce the end reaction in the same volume of pure water containing only the starch indicator.

The decinormal solution of iodine was made by dissolving 12·65 grms. of carefully resublimed iodine in potassium iodide (proved free from iodate) and diluting to a liter. The centinormal solution was made by diluting the stronger solution. The standardizing was effected by comparison with a solution of arsenious oxide containing 4·95 grm. to the liter. This mode of fixing the value of the solution should, and, as the sequel proved, did indicate the correct standard, but for the sake of confirmation the value of the arsenic solution was redetermined by titration against iodine specially purified by subliming off potassium iodide, re-subliming between watch-glasses, and exposing during forty-eight hours over sulphuric acid. Portions of the iodine thus prepared were weighed in a glass-stoppered weighing bottle, dissolved in the same without danger of volatilization by introducing pure solid potassium iodide and a little water, and diluted and treated with the solution of arsenious acid measured from a burette until the color of iodine vanished. The excess of arsenious oxide was determined by titrating against the standard solution of iodine whose value in terms of measured portions of the solution of arsenious oxide was perfectly known.

In Series K are detailed experiments which follow the line marked out for the separation of iodine from chlorine and bromine in the haloid salts, excepting that the iodide was entirely omitted for the purpose of discovering whether hydrochloric and hydrobromic acids possess reducing action upon arsenic acid under the conditions. The evidence is plain that no arsenious oxide is formed by the action of 0·5 grm. of sodium chloride upon 2 grm. of the arseniate under the circumstances as given.

Hydrobromic acid, on the contrary, is slightly decomposed with the evolution of bromine enough to give visible color to the concentrated liquid, but the amount of bromine lost, as indicated by the arsenious acid produced in its evolution, is only 0·0003 grm. for 0·5 grm. of potassium bromide, and 0·0001 grm. for 0·1 grm. of the bromide. Further experiments indicated, however, that concentration cannot go on to a volume less than 35 cm³ without causing serious loss when the maximum amount of bromide is present.

SERIES K.

H_2SO_4 [1:1].	H_2KAsO_4.	NaCl.	KBr.	Final volume.	Iodine correspondi'g to As_2O_3 reduced.	Chlorine corresponding (average).	Bromine corresponding (average).
					grm.	grm.	grm.
20 cm³	2 grm.	0·5 grm.	--	35 cm³	0·0000		
20	2	0·5	--	35	0·0000	0·0000	----
20	2	0·5	--	35	0·0000		
20	2	--	0·1 grm.	35	0·0003		
20	2	--	0·1	35	0·0001	----	0·0001
20	2	--	0·1	35	0·0001		
20	2	--	0·5	35	0·0005		
20	2	--	0·5	35	0·0005	----	0·0003
20	2	--	0·5	35	0·0005		

In Series L are given the results of twenty-six determinations of iodine by the method outlined.

Upon inspection of these results it appears that the method is good and reliable under all the conditions tested.

When neither chloride nor bromide is present, the iodine is determinable with a mean error of 0·0002 grm.

When sodium chloride accompanies the iodide, the results show a loss of arsenious oxide and a consequent apparent deficiency of iodine—as we should expect in accordance with the indications of Series I. This deficiency proves to be proportional to the amount of iodide broken up, or the arsenious oxide thus produced. For 0·56 grm., approximately, of potassium iodide and 0·5 grm. of sodium chloride the deficiency measured in iodine amounted to 0·0011 grm. When the potassium iodide is decreased ten-fold (or more) the deficiency falls to

0·0002 grm. It should be recalled, too, in this connection that the results of Series J pointed to increasing volatility of the arsenic with the increase of the sodium chloride present.

SERIES L.

No.	H_2SO_4 [1:1].	H_2KAsO_4.	NaCl.	KBr.	Final vol.	KI taken.	Theory for Iodine.	Iodine found.	Error.	Average error.
		grm.				grm.	grm.	grm.	grm.	grm.
(1)	20 cm³	2	----	----	35 cm³	0·5616	0·4080	0·4079	0·0001—	
(2)	20	2	----	----	35	0·5630	0·4091	0·4086	0·0005—	
(3)	20	2	----	----	35	0·5622	0·4083	0·4086	0·0003+	
(4)	20	2	----	----	35	0·0506	0·0400	0·0396	0·0004—	
(5)	20	2	----	----	35	0·0506	0·0400	0·0391	0·0009—	0·0002—
(6)	20	2	----	----	35	0·0506	0·0400	0·0400	0·0000	
(7)	20	2	----	----	35	0·0506	0·0400	0·0401	0·0001+	
(8)	20	2	----	----	35	0·0051	0·0040	0·0037	0·0003—	
(9)	20	2	----	----	35	0·0051	0·0040	0·0038	0·0002—	
(10)	20	2	0·5	----	35	0·5611	0·4077	0·4066	0·0011—	
(11)	20	2	0·5	----	35	0·5619	0·4082	0·4073	0·0009—	0·0011—
(12)	20	2	0·5	----	35	0·5624	0·4086	0·4073	0·0013—	
(13)	20	2	0·5	----	35	0·0506	0·0400	0·0402	0·0002+	
(14)	20	2	0·5	----	35	0·0506	0·0400	0·0395	0·0005—	
(15)	20	2	0·5	----	35	0·0051	0·0040	0·0037	0·0003—	0·0002—
(16)	20	2	0·5	----	35	0·0051	0·0040	0·0037	0·0003—	
(17)	20	2	----	0·5	35	0·5619	0·4082	0·4092	0·0010+	
(18)	20	2	----	0·5	35	0·5697	0·4138	0·4136	0·0002—	0·0008+
(19)	20	2	----	0·5	35	0·5622	0·4083	0·4099	0·0016+	
(20)	20	2	----	0·5	35	0·0506	0·0400	0·0410	0·0010+	
(21)	20	2	----	0·5	35	0·0506	0·0400	0·0404	0·0004+	
(22)	20	2	----	0·5	35	0·0051	0·0040	0·0048	0·0008+	0·0008+
(23)	20	2	----	0·5	35	0·0051	0·0040	0·0049	0·0009+	
(24)	20	2	0·5	0·5	35	0·5626	0·4087	0·4083	0·0004—	
(25)	20	2	0·5	0·5	35	0·5660	0·4112	0·4111	0·0001—	0·0003—
(26)	20	2	0·5	0·5	35	0·5622	0·4083	0·4079	0·0004—	

The presence of potassium bromide results in the liberation of minute amounts of bromine and a consequent increase in the arsenious oxide and apparent excess of iodine. The mean error due to this cause is 0·0008 grm. for 0·5 grm. of the bromide, and the variation in the quantity of iodide present is without effect upon it.

The simultaneous action of the chloride and bromide tends, of course, to neutralize the error due to each. Thus, in the mixture weighing about 1·5 grm. and consisting of sodium chloride, potassium bromide, and potassium iodide in equal parts, the mean error amounts to 0·0003 grm. —. The largest error in the series is 0·0016 grm. +, when the bromide was at its maximum and no chloride was present; and the next largest was 0·0013 grm. — when the chloride was at its maximum and no bromide was present.

It is obvious that when the amounts of chloride and bromide present are known approximately it is possible to apply correc-

tions which shall eliminate errors in the indicated amount of iodine due to the action of these substances. From the averages of Series L it is apparent that the amount to be added in each case may be obtained by multiplying the product of the weights in grms. of sodium chloride and potassium iodide by the constant 0·004; and the amount to be subtracted, by multiplying the weight in grms. of potassium bromide by 0·0016. Thus, for example, the correction in (24) will be 0·0011 grm. + (=0·5 × 0·56 × 0·004) and 0·0008 grm. − (=0·5 × 0·0016). The individual results of Series L thus corrected will stand as follows:

No. of Exp.	Theory for Iodine.	Corrected amount of Iodine found.	Error.	Mean error.
(1)	0·4080 grm.	0·4079 grm.	0·0001 grm. −	
(2)	0·4091	0·4086	0·0005 −	
(3)	0·4083	0·4086	0·0003 +	
(4)	0·0400	0·0396	0·0004 −	
(5)	0·0400	0·0391	0·0009 −	
(6)	0·0400	0·0400	0·0000	
(7)	0·0400	0·0401	0·0001 +	
(8)	0·0040	0·0037	0·0003 −	
(9)	0·0040	0·0038	0·0002 −	
(10)	0·4077	0·4077	0·0000	
(11)	0·4082	0·4084	0·0002 +	
(12)	0·4086	0·4084	0·0002 −	
(13)	0·0400	0·0403	0·0003 +	0·0001 grm. −
(14)	0·0400	0·0396	0·0004 −	
(15)	0·0040	0·0037	0·0003 −	
(16)	0·0040	0·0037	0·0003 −	
(17)	0·4082	0·4084	0·0002 +	
(18)	0·4138	0·4128	0·0010 −	
(19)	0·4083	0·4191	0·0008 +	
(20)	0·0400	0·0402	0·0002 +	
(21)	0·0400	0·0396	0·0004 −	
(22)	0·0040	0·0040	0·0000	
(23)	0·0040	0·0041	0·0001 +	
(24)	0·4087	0·4086	0·0001 −	
(25)	0·4112	0·4114	0·0002 +	
(26)	0·4083	0·4082	0·0001 −	

The mode of proceeding in the analysis of a mixture of alkaline chlorides, bromides and iodides, according to this method may be briefly summarized as follows:

The substance (which should not contain of chloride more than an amount corresponding to 0·5 grm. of sodium chloride, nor of bromide more than corresponds to 0·5 grm. of potassium bromide, nor of iodide much more than the equivalent of 0·5 grm. of potassium iodide) is dissolved in water in an Erlenmeyer beaker of 300 cm^3 capacity, and to the solution are added 2 grms. of dihydrogen potassium arseniate dissolved in water, 20 cm^3 of a mixture of sulphuric acid and water in equal vol-

umes, and enough water to increase the total volume to 100 cm^3, or a little more. A platinum spiral is introduced, a trap made of a straight two-bulb drying-tube cut off short is hung with the larger end downward in the neck of the flask, and the liquid is boiled until the level reaches the mark put upon the flask to indicate a volume of 35 cm^3. Great care should be taken not to press the concentration beyond this point on account of the double danger of losing arsenious chloride and setting up reduction of the arseniate by the bromide. On the other hand, though 35 cm^3 is the ideal volume to be attained, failure to concentrate below 40 cm^3 introduces no appreciable error. The liquid remaining is cooled and nearly neutralized by sodium hydrate (ammonia is not equally good), neutralization is completed by hydrogen potassium carbonate, an excess of 20 cm^3 of the saturated solution of the latter is added, and the arsenious oxide in solution is titrated by standard iodine in the presence of starch.

With ordinary care the method is rapid, reliable and easily executed, and the error is small. In analyses requiring extreme accuracy all but accidental errors may be eliminated from the results by applying the corrections indicated.

ART. XXVI.—*On the Mineral Locality at Branchville, Connecticut:* Fifth Paper; by GEORGE J. BRUSH and EDWARD S. DANA. *With analyses of several manganesian phosphates;* by HORACE L. WELLS.

IT is now nearly twelve years since we published our first paper* upon the Branchville minerals. It will be remembered that the material which formed the basis of our early work was that which Mr. Fillow had brought to light in his excavations, some two years previous, in search for mica. It was this lot of minerals, sagaciously selected and preserved by Mr. Fillow, that we found so remarkably rich in phosphates of manganese, including a number of new and interesting species.† During

* See this Journal, xvi, 33, 114, July and August, 1878; Second Paper, xvii, 359, 1879; Third Paper, xviii, 45, 1879; Fourth Paper. xx, 257, 1880.

† It may be useful here to recall that our investigations have shown that, besides apatite, amblygonite and some others, the following phosphates are present:

Lithiophilite: a manganese triphylite, essentially $LiMnPO_4$; massive, cleavable, of a salmon-pink to clove-brown color.

Eosphorite: a manganese childrenite, essentially $MnAl(OH)PO_4 + 2H_2O$; in orthorhombic crystals and massive, of a rose-pink color.

Triploidite: near triplite, essentially $Mn(MnOH)PO_4$ in fibrous aggregates and monoclinic crystals isomorphous with wagnerite.

Dickinsonite: a phosphate of manganese, iron and sodium; in bright green chlorite-like foliated aggregates, rarely in pseudo-rhombohedral crystals.

the years of 1878 and 1879, we carried on a somewhat extended search for these minerals in the ledge from which they had been obtained, but the spot from which the most interesting specimens had been derived was very unfavorably situated for work, being ten feet or more below the level of the ground, and our efforts were only in part successful. Some of the results we have already announced in subsequent papers.

Perhaps the most important result of our early explorations was to prove the presence of large amounts of potash feldspar (microcline) and quartz in the vein—in fact, before we ceased our private work, we had brought to the surface several hundred tons of these minerals. This material was of so excellent quality for technical use and the supply seemed to be so large that negotiations were presently entered into between Mr. Fillow, the owner of the property, and the Messrs. Smith, of the Union Porcelain Works, of Greenpoint, New York, with the final result of the sale of the property to the latter gentlemen. This was accomplished in 1880. Since that time the work of quarrying for feldspar and quartz has been carried forward uninterruptedly and with gratifying success; up to the present time Mr. Fillow informs us that from three to four thousand tons of feldspar and four thousand tons of quartz have been shipped from the locality. The arrangement has proved also a very successful one from a scientific point of view. The Messrs. Smith have very liberally placed at our disposal all the material obtained from the locality which was of no technical value, while the daily presence of Mr. Fillow, with his active interest and keen eye, has resulted in saving for science practically everything which the locality has yielded. The covering of earth was early removed, and the ledge opened to as great a depth as the drainage would allow; since then the drain has been repeatedly cut deeper until in the summer of 1888, ten years after our first work, the time to which we had been constantly looking forward arrived and the deep spot from which the first supply of phosphates came was reached.*

In the meantime, however, the work had not been unproductive, and the contents of our third paper upon certain deposits of lithiophilite, eosphorite and other associated minerals, and of our fourth paper upon the spodumene and its

Reddingite: $(Mn,Fe)_3PO_4+3H_2O$; in pinkish orthorhombic crystals near scorodite in form, also in granular masses.

Fairfieldite: a phosphate of manganese and calcium $(Ca,Mn)_3P_2O_8+2H_2O$; triclinic, usually in foliated masses, of a white or yellowish color and pearly to adamantine luster.

Fillowite: a phosphate of manganese, iron, calcium and sodium; in granular aggregates of monoclinic crystals of a honey-yellow color and resinous to adamantine luster.

* It may be added that at present the depth of the opening is some 40 feet and is length and breadth about 160 by 45 feet.

alteration-products, show in part what was accomplished. In addition to what is mentioned in these papers, the locality has at several different times yielded a not inconsiderable amount of uraninite, in part in octahedral crystals with a specific gravity of 9·3; this has been investigated chemically by Comstock.* With the uraninite have been found two or more uranium phosphates which have not as yet been thoroughly studied. Columbite has also been found in considerable quantity, aggregating more than 500 pounds. This occurs in crystalline masses, and in part well developed crystals and groups of crystals in parallel position of remarkable size. It has a specific gravity of 5·73, and as shown by an analysis by T. B. Osborne† contains 19·2 per cent of Ta_2O_5. Another kind of columbite has also been found in minute reddish brown translucent crystals usually implanted upon the spodumene.‡ This variety Comstock has shown to be exceptionally interesting in the fact that it contains manganese with practically no iron, and further has the niobium and tantalum in the ratio of 1:1; it has a specific gravity of 6·59. Other points of interest that have been brought out are the occurrence on a rather abundant scale of a mineral, both massive and indistinctly fully crystallized, which resembles cyrtolite but has not yet been investigated; also of smoky quartz, in part well crystallized, and remarkable for its richness in fluid inclusions (CO_2, etc.) as described microscopically and chemically by Hawes and Wright;§ also of beryl in large columnar masses sometimes two feet or more in length; still further of albite in finely crystallized specimens. Apatite has been found in a variety of forms; one variety, of a dark bluish green, has been found by Penfield‖ to contain 10·6 per cent of MnO. Other kinds are interesting crystallographically and resemble the Swiss crystals in habit and complexity. Mica has been obtained in limited amount of a merchantable form (300 pounds of plates cut to pattern); the most common variety, however, is that occurring in curved plates, presenting a smooth convex surface like a watch-glass; these aggregates have a radiated as well as concentric structure. Specimens of the Branchville mica have been analyzed by Rammelsberg.¶

The most important developments, however, have been those of the summers of 1888 and 1889, when considerable quantities of the manganesian phosphates were brought to light. This result has been especially gratifying to us, since it has given us specimens of all but one of the new species described in 1878 (cf. p. 202), several of which we had almost despaired of

* This Journal, xix, 220, 1880.
‡ Ibid., xix, 131, 1880.
‖ Ibid., xix, 367, 1880.
† This Journal, xxx, 336, 1885.
§ Ibid., xxi. 203. 209, 1881.
¶ Jahrb. Min., ii, 224, 1885.

finding again. It has also afforded another new member of the triphylite group, a sodium-manganese phosphate, which we shall call *natrophilite*. Besides this we have identified another phosphate of manganese, and one which from the first we had hoped to find, viz: the rare mineral *hureaulite*, thus far only certainly known from Limoges, Commune of Hureaux, in France.

The general method of occurrence of the phosphates of manganese is such as to confirm the opinion that we have expressed in a former paper, that the manganesian triphylite or lithiophilite is the parent species. This is beyond all doubt an original mineral in the vein, occurring intimately associated with the albite, quartz and spodumene. With it, sometimes entirely enclosed by it, we find another of the Branchville species, triploidite, which seems to be also an original mineral.

The masses of lithiophilite are as a rule unaltered, showing only a little oxidation on the outer surfaces, and on the fracture surfaces an occasional thin film of a bright blue crystallized mineral in minute amount, resembling vivianite. In some few cases they have a distinct though rough crystalline form, and the planes 110, 120 and 021 have been identified; one of these rough crystals is no less than eighteen inches in length and weighs fifteen pounds. The angles measured are mere approximations, but they are interesting as showing, as has been assumed, that the form of lithiophilite is the same as that of triphylite. We may add here that a small crystal found some years ago resembles fig. 450 in Dana's System.

	Lithiophilite.	Triphylite (Tschermak).
$110 \wedge 1\bar{1}0 =$	48°	47°
$110 \wedge 120 =$	17 –18°	17 31′
$010 \wedge 021 =$	42	43 31

The cleavage angle $110 \wedge 1\bar{1}0$ was found to be 48° 30′ to 49°. Occasionally the masses of lithiophilite are extensively changed; this is true especially of some of the large nodular inclusions in the vein. It is most interesting in these masses to note the change from the perfectly fresh lithiophilite through a zone in which the green chlorite-like dickinsonite is more or less distinctly represented to the hureaulite beyond. This change of the lithiophilite into hureaulite can often be observed, and the interpenetration of the two minerals is well shown under the microscope in sections cut parallel to the basal cleavage. A thin line of eosphorite often crosses the hureaulite. Sometimes with the dickinsonite we have also fairfieldite in clear foliated masses, and reddingite in light pinkish crystals and crystalline masses. It is impossible to lay down any general rules in regard to the order of occurrence of these minerals or their method of arrangement. On the contrary they occur

closely together, now one and now another prominent, and it is not uncommon to find five or six of the phosphates in characteristic form on a single hand specimen a few square inches in surface. In one such specimen, for example, we have at one extremity lithiophilite and triploidite, then hureaulite and natrophilite interpenetrated by a narrow zone of eosphorite and again lithiophilite. In another specimen which gives a section into the interior of a nodular mass, we pass from the exterior albite through a nondescript zone blackened by oxidation and showing some dickinsonite, through distinct foliated masses of the same mineral enclosing patches of natrophilite, then hureaulite abundant with fairfieldite and some reddingite, and finally the unchanged lithiophilite.

Much of the material is of the most ill-defined and problematical character, being an intimate mixture sometimes of eosphorite and quartz, such as we have before described, or of others of the phosphates in indistinct form. Typical specimens of the different species are as characteristic as could be desired and recognized at once; in others less characteristic they resemble one another so closely that identification is often a matter of much difficulty. It may be added that much of the triploidite can hardly be told by the eye from a massive red garnet commonly associated with it, while the fairfieldite similarly resembles the albite; in these cases, however, a simple test of hardness is all that is required. We go on now to a detailed account of some of the more interesting species identified.

Natrophilite.

The sodium-manganese member of the triphylite group, to which we give the name *natrophilite*, has been identified only in the material obtained during the last summer. It occurs sparingly, usually closely associated with lithiophilite, and upon a superficial examination could be confounded with it, although distinguishing characters are not wanting. It appears in cleavable masses for the most part, the cleavage surfaces often broad, and showing something of a pearly luster. Occasionally smaller grains appear imbedded in the cleavage mass, and these show at times a more or less distinct crystalline form. On one of these the usual planes of triphylite were identified, 110, 120, 021, 001 (cleavage). The angles could not be obtained accurately but were sufficient to determine the forms, viz:

	Natrophilite.	Triphylite.
$110 \wedge 1\bar{1}0 =$	50° 30	47°
$120 \wedge 1\bar{2}0 =$	87	82 1′
$001 \wedge 032 =$	47 –49°	46 29

In crystalline form, then, it agrees as was to be expected with triphylite and lithiophilite. Optically it also corresponds so far

as it has been investigated; the optic axes lie in basal section and the acute bisectrix (positive) is normal to the brachypinacoid. The characteristic basal cleavage is always a prominent character, but the brachydiagonal cleavage 010 is less distinct than is shown by lithiophilite, and the prismatic cleavage (110) is interrupted; the measured angle was 50°; these cleavages are seen more clearly in thin sections. The fracture is conchoidal, more perfectly so than with lithiophilite. The color is a rather deep wine-yellow, much like that of the Brazilian topaz. The luster is brilliant resinous to nearly adamantine; it was, in fact, the brilliancy of the luster which first attracted our attention, and which is, so far as the eye is concerned, its most distinguishing character. The mineral itself is perfectly clear and transparent, but the masses are much fractured and rifted. The surfaces are often covered by a very thin scale of an undetermined mineral, having a fine fibrous form, a delicate yellowish color and silky luster. This same mineral penetrates the masses wherever there is a fracture surface of cleavage or otherwise. What the exact nature of this mineral is we are unable to say, since the amount is too small to admit of a satisfactory determination—it appears to be a manganesian phosphate. It is evidently an alteration-product and would seem to imply that natrophilite is rather subject to easy chemical change. In any case this silky film is one of the characteristic features of the mineral, and directs attention to it at once even over the surface of a hand specimen where it is associated with lithiophilite and perhaps three or four other of these phosphates.

Before the blowpipe natrophilite fuses very easily and colors the flame intensely yellow, thus being at once distinguished from lithiophilite. It also gives the usual reactions for manganese. The following is an analysis of natrophilite made by Wells. The specific gravity on two fragments was found to be 3·40 and 3·42.

	I.	II.	III.	Mean.		
P_2O_5	41·03	----	---	41·03÷142=	·289=1	=1
MnO	38·19	----	----	38·19÷ 71=·538	·580=2·01	=2
FeO	3·06	----	----	3·06÷ 72=·042		
Na_2O	----	16·77	16·81	16·79÷ 62=·271	·279=0 97	=1
Li_2O	----	0·20	0·19	0·19÷ 23=·008		
H_2O	----	0·40	0·45	0·43		
Insol.	0·81	0·81	0·81	0·81		
				100·50		

The formula is therefore $\overset{I}{R}_2O \cdot 2\overset{II}{R}O \cdot P_2O_5$ or $\overset{I}{R}\overset{II}{R}PO_4$, or essentially $NaMnPO_4$. It will be noticed that iron is present in very small amount only (3 p. c.) and of lithia there is hardly more than a trace (0·2 p. c.). With the discovery of natrophil-

ite, the triphylite group receives an important addition, and we now have:

Triphylite, $LiFePO_4$ } Connected by many intermediate
Lithiophilite, $LiMnPO_4$ } compounds, $Li(Fe, Mn)PO_4$.
Natrophilite, $NaMnPO_4$.

These three species are, as is to be expected, closely isomorphous. To them is also related in composition and in some degree in form the new sodium-beryllium phosphate, beryllonite, $NaBePO_4$, which was described by one of us a year and a half ago.*

The relation of natrophilite in origin to the common lithiophilite is an interesting question. In view of the extensive changes that, as we have shown, have taken place in the spodumene, by which the lithium has been removed and its place taken more or less fully by sodium, or sodium and potassium, it is natural to suggest that a similar change has resulted in forming the $NaMnPO_4$ out of $LiMnPO_4$, and this we regard as very probable. Its limited method of occurrence suggests the same thing, although it must be remarked at the same time that it seems to pass into hureaulite as readily as the lithiophilite. If in fact formed from lithiophilite, the change probably took place before the formation of most of the other phosphates.

Hureaulite.

Perhaps the most interesting of recent developments at Branchville is the discovery of the rare mineral hureaulite. Thus far our knowledge of hureaulite has been limited to the account of crystals from Limoges by Dufrénoy† and the later and more thorough description by Damour and DesCloizeaux.‡ In addition we have only the single remark by Websky that it probably occurs at Michelsdorf, Silesia, with sarcopside.

The crystals described by DesCloizeaux belong to three varieties showing two distinct types of form, though having the same composition, as shown by Damour. These varieties are respectively violet-rose, brownish orange and pale rose pink in color. Their crystallographic relation to each other is anomalous, in fact, it would be difficult to find another case equally so. The crystals of the two types have the fundamental prism in common, but otherwise no plane of the one occurs on the other, and what is more remarkable, the symbols assigned to a number of the planes of the second type are complex in the extreme. The axial ratio calculated from DesCloizeaux's fundamental measurements is

$$\dot{a} : \dot{b} : \dot{c} = 1{\cdot}6977 : 1 : 0{\cdot}8887; \quad \beta = 89° \ 27'.$$

The planes observed on crystals of the two types are as follows:

* This Journal, xxxvi, 290, Oct., 1888; xxxvii, 23, Jan., 1889.
† Ann. Chim. Phys., xli, 338, 1829. ‡ Ibid, III, liii, 293, 1858.

First type				Second type.			
			DesCl.				DesCl.
b	010	i-$\bar{i}$	g	a	100	i-i	h^1
c	001	O	p	m	110	I	m
m	110	I	m	o	105	$-\frac{1}{5}$-i	o^5
g	301	-3-i	$o\frac{1}{3}$	a	$\bar{1}\bar{5}\cdot 0\cdot 8$	$\frac{1}{8}$-i	$a\frac{8}{15}$
e	011	1-$\bar{i}$	e^1	δ	435	$-\frac{3}{5}$-$\frac{4}{5}$	δ
u	$\bar{3}11$	3-3	u	k	$\bar{1}\bar{9}\cdot 5\cdot 8$	$\frac{1}{8}\frac{9}{9}$-$\frac{1}{8}\frac{9}{6}$	k
t	$\bar{3}41$	4-$\frac{3}{4}$	t	x	$\bar{1}\bar{1}\cdot 9\cdot 10$	$\frac{1}{10}$-$\frac{1}{9}$	x
				ε	$\bar{9}\cdot 11\cdot 10$	$\frac{1}{10}$-$\frac{11}{9}$	ε

The Branchville crystals, like those from Limoges, vary in color from pale violet to reddish brown and deep orange-red. The habit of the crystals, however, is nearly constant and the angles also so far as our measurements have gone; they correspond to the second type of the Limoges crystals. The crystals are not easy to decipher, since they are very small, united by parallel grouping and as a rule present only a few planes in such a way as not to exhibit the symmetry. The angles are not as accurate as could be desired, although the crystals are much better than those of Limoges, since DesCloizeaux gives his observed angles to whole degrees in many cases and the majority are stated to be approximations only.

For the sake of greater simplicity of symbols, the position of DesCloizeaux is modified somewhat in that his plane 105 (o^5) is taken as the base and the pyramid δ is made the unit pyramid.

For fundamental angles the following have been assumed:

$$100 \wedge 001 = 84^\circ\ 1'$$
$$110 \wedge 1\bar{1}0 = 62^\circ\ 21'$$
$$\bar{1}10 \wedge \bar{4}01 = 70^\circ\ 54'$$

whence we obtain:

$$\dot{a} : b : \dot{c} = 1{\cdot}9192 : 1 : 0{\cdot}5245;\ \beta = 84^\circ\ 1'.$$

The observed planes with the symbols of the corresponding planes so far as observed by DesCloizeaux are as follows:

			DesCloizeaux.	
a	100	i-i	100	h^1
c	001	O	105	o^5
m	110	I	110	m
a	$\bar{4}01$	4-$\bar{i}$	$\bar{1}5\cdot 0\cdot 8$	$a\frac{8}{15}$
β	$\bar{5}01$	5-$\bar{i}$		
p	223	$-\frac{2}{3}$		
δ	111	-1	435	δ
e	$\bar{5}21$	2	$\bar{9}\cdot 11\cdot 10$	ε
k	$\bar{5}11$	5-5	$\bar{1}\bar{9}\cdot 5\cdot 8$	k
z	$\bar{6}21$	6-3		
l	$\bar{8}41$	8-2		

The attempt to transform the symbols of DesCloizeaux, according to the usual methods, into those required by this change of position meets with only partial success. Thus the plane $\bar{1}\bar{9}\cdot 5\cdot 8$ becomes by the transformation $\bar{4}11$ while the

observed angles of DesCloizeaux make it for the axial ratio here taken $\breve{5}11$. As will be seen below the angles of a number of forms on the Branchville hureaulite agree pretty well with the angles measured by DesCloizeaux, with the single exception of the prism. For this he found 119°, while we make it for the Branchville crystals 124° 42′. It is this discrepancy which causes the want of agreement which we have just alluded to. Furthermore, it is seen that the complex symbols of several of the planes, in DesCloizeaux's position and referred to his axes, become simplified when referred to the axes here adopted. Of the planes noted by DesCloizeaux on type 2, all but one ($\bar{1}\bar{1}\cdot 9\cdot 10$) it will be seen, occurs on the Branchville crystals and to this the symbol $\breve{5}32$ probably belongs in our position. Of the forms of the first type, only the prism occurs with us, but to the other planes the probable symbols in our position may be assigned.

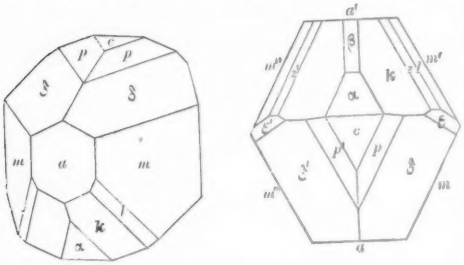
DesCloizeaux.			DesCloizeaux.		
001	p	$\bar{1}03$	$\breve{5}11$	u	$\bar{1}\breve{5}\cdot 3\cdot 2$?
011	c^1	$\bar{1}53$	$\breve{5}41$	t	$\breve{6}61$?

The following table gives the more important angles calcu-

	Branchville.		DesCloizeaux.	
	Calculated.	Measured.	Calculated.	Measured.
$100 \wedge 110$	*62° 21′	62° 18′, 62° 25′, 62 27 62 35 62 45	59°	59°
$001 \wedge 100$	*84 1	83 26	83 29′	83° 39′
" $\bar{1}00$	95 59	96 9	96 31	96 30
" $\breve{1}03$	5 13½			(5 58)
" $\bar{4}01$	50 49		50 42	50 50
$\bar{1}00 \wedge \bar{4}01$	45 10	45 54	45 49	45 40
$100 \wedge 223$	74 47½			
" 111	71 25	71 9		
$\bar{1}00 \wedge \bar{8}41$	47 59			
" $\wedge \breve{5}11$	41 40	42 12, 42 14, 42 35		42 10
$001 \wedge 223$	21 3	21 3, 21 58		
" $\wedge 111$	29 46	29 40, 29 28	30 40	29 25
" $\wedge 110$	87 14	87°, 87° 4′, 87 12′	86 42	86
" $\bar{2}21$	51 17		50 17	50 29
" $\wedge \breve{5}11$	59 30			59 30
" $\wedge \bar{1}10$	92 46	92° 56′		
$22\breve{3} \wedge 2\breve{2}3$	37 9	37 37		
$111 \wedge 1\bar{1}1$	52 14½	51 54	52 13	51
$511 \wedge \breve{5}\bar{1}1$	35 58	36 7, 36 31	38 33	37
$110 \wedge 111$	57 28	57 32, 57 22, 57 42	56 2	55 45
" 223	66° 11′	66 12, 67 3		
$\bar{1}10$ $\bar{2}21$	41 29	42 1	43 2	43
" $\wedge \breve{5}11$	51° 9′	51 40, 51 50, 51 52	48 57	49
" $\wedge \bar{8}41$	25° 13′	25 13, 25° 22′		
" $\wedge \bar{4}01$	*70° 54′	70 53, 71° 19′		

lated from our axial ratio compared with our measurements and also with the *measured* angles of DesCloizeaux. It is seen that the correspondence between our measured and calculated angles is not in all cases as great as could be desired, although as much as could perhaps be expected from the nature of the material. It has been stated that the crystals are often grouped in parallel position, but as is common in such cases, the parallelism is not perfect and furthermore the parts show slight variations in position, even when the planes are smooth, which are doubtless to be referred to the same cause.

The habit of the Branchville crystals is short prismatic as shown on figure 1; a basal projection of a more complex form is given in fig. 2. The grouping in parallel position gives rise to a repetition of the prismatic planes which may result in a deep striation or furrowing of this face. Besides this, the zone of planes *m*, *l*, *k*, *a*, is often striated or channeled parallel to their common direction of intersection. The crystals show rather perfect cleavage parallel to the orthopinacoid. For analysis, carefully selected portions of the purest crystals were taken by Prof. Wells. The specific gravity was found to be 3·149. The results are satisfactory as agreeing fully with those of Damour and leading to the same formula. For comparison we quote Damour's analysis of the pale rose crystals which differs but little from that of the yellow crystals; it is to be noted that the violet crystals (type I) have not been analyzed and it is possible that some difference in composition may explain the difference noted in the form. The Branchville mineral contains a little less iron than the Limoges.

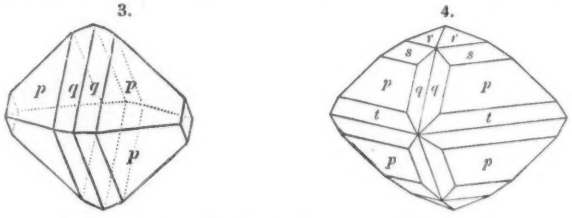


	Branchville. G.=3·149				Limoges. rose, G.=3·185
	I.	II.	Mean.		
P_2O_5	38·28	38·44	38·36	·270=1·00=2	37·83
FeO	4·76	4·37	4·56 ·063	·676=2·50=5	8·73
MnO	42·29	----	42·29 ·596		41·80
CaO	0·94	----	0·94 0·17		
H_2O	12·25	12·15	12·20	·678=2·51=5	11·60
Quartz	1·76	----	1·76		Gangue 0·30
			100·11		100·26

The formula is $5RO \cdot 2P_2O_5 \cdot 5H_2O$ or $H_2R_5(PO_4)_4+4H_2O$. The percentage composition calculated for manganese only is: P_2O_5 38·96, MnO 48·69, H_2O 12·35=100.

Reddingite.

The species reddingite has been known thus far only in a few specimens, showing it in a granular form of a reddish color, or rarely in octahedral crystals often superficially black from oxidation. The material first found though scanty was sufficient to admit of the determination of the form, which was shown to be similar to that of scorodite and strengite. Among the specimens recently discovered, reddingite is not uncommon, and we have been gratified to obtain it not only well crystallized but also in massive form, perfectly fresh and unaltered. The color is a pale rose-pink, often hardly more than a pinkish-white. The most intimately associated minerals are fairfieldite and dickinsonite, the latter of which is often imbedded in it in isolated scales or more often in stellate groups of green folia. The octahedral habit of the crystals, which appear in occasional cavities, is usually apparent at a glance, but not infrequently the crystals are distorted by the elongation of a pair of pyramidal planes which gives them a misleading oblique prismatic appearance. The common form



of the crystals is shown in fig. 3 from our former paper. Some of the crystals are more complex (fig. 4) and show also the unit pyramids r, s and t, whose symbols are respectively 338, 223, 774. These planes do not give sharp measurements but the angles are sufficient for identification. The axes taken are those previously obtained by us, viz:

$$\breve{a} : \bar{b} : \dot{c} = 0{\cdot}8678 : 1 : 0{\cdot}9485$$

and the measured and calculated angles are,

	Measured,	Calculated.
111 ∧ 338 =	20° 11′	20° 9′
111 ∧ 223 =	10° 10′	9° 54′
111 ∧ 774 =	15° 41′	15° 46′

It seemed especially desirable to have a new analysis of this species, both because the material was more abundant and

better than what we had had before, and also since the composition—though in fact fully established—may have appeared to some anomalous, in view of its failure to correspond with that of scorodite and strengite in the degree of oxidation of the manganese and in the amount of water. The new analysis by Wells fully confirms the former one made by him, only differing in the larger percentage of ferrous iron present.* This analysis of a carefully selected portion with a specific gravity of 3·204, gave:

	I.	II.		
P_2O_5	34·90	----	+ 142 = ·246	= 1·00 = 1
FeO	17·13	----	+ 72 = ·238	
MnO	34·51	----	+ 71 = ·486	·735 = 2·99 = 3
CaO	0·63	----	+ 56 = ·011	
H_2O	13·18	13·18	+ 18 = ·732	= 2·98 = 3
Quartz	0·13	----		
	100·48			

The formula is hence $R_3(PO_4)_2 + 3H_2O$, and if R=Fe:Mn=1:2, this requires P_2O_5 34·64, FeO 17·56, MnO 34·63, H_2O 13·17=100.

Fairfieldite.

Fairfieldite appears among the specimens recently obtained not infrequently, and in a form much fresher and purer than that in which we had it before. It is usually in foliated masses intimately associated with reddingite and fairfieldite, and hardly less so with hureaulite. The color varies from white to yellowish or greenish white; it is usually perfectly transparent and the luster is very brilliant, varying from adamantine to pearly according to the surface on which it is viewed, the latter on the surface of perfect cleavage. A tendency to crystallization is at times apparent but no crystals suitable for measurement have been found, which is to be regretted since the early results left much to be desired. An analysis of the perfectly fresh mineral has been made by Wells. This agrees with those of Penfield previously published; the amount of iron is less and that of the manganese greater, but it is worthy of note that the ratio of 2:1 for Ca:Mn+Fe is still maintained.† The analysis of pure material having a specific gravity of 3·07 is as follows:

* The earlier analysis gave FeO 5·43, MnO 46·29.

† It is interesting to call attention here to the identification of fairfieldite by Sandberger at Rabenstein, Jahrb. Min., i. 185, 1885. It is also worthy of note that a new hydrous phosphate of ferrous iron and calcium, near fairfieldite but with $2\frac{1}{2}H_2O$, has been recently named messelite by Muthmann (Zs. Kryst., xvii, 93, 1889); like fairfieldite it is triclinic. Furthermore the brandtite of Nordenskiöld is $Ca_2Mn(AsO_4)_2 + 2H_2O$, corresponding exactly to fairfieldite, Œfv. Ak. Stockh., 489, 1888, Groth, Tab. Ueb. Min., p. 80, 1889.

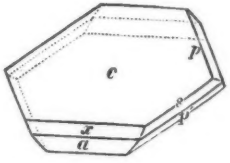
P_2O_5	[37·69*]	÷ 142 = ·265		= 1·00 = 1
FeO	3·42	÷ 72 = ·047	·292	= 1·10 = 1
MnO	17·40	÷ 71 = ·245		
CaO	30·02	÷ 56 = ·536		= 2·02 = 2
H_2O	9·81	÷ 18 = ·545		= 2·06 = 2
Quartz	1·66			
	100.00			

The formula is hence essentially $Ca_2Mn(PO_4)_2+2H_2O$, which requires P_2O_5 39·34, MnO 19·67, CaO 31·02, H_2O 9·97=100. This analysis confirms the earlier one by Penfield and further makes it probable that there is a definite ratio of 1 : 2 for Mn (with Fe) : Ca.

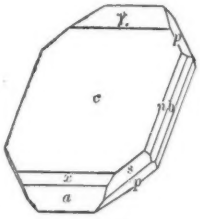
Dickinsonite.

One of the most remarkable and novel of the species first described from Branchville was the chlorite-like dickinsonite—a mineral of a bright green color, micaceous structure and pseudo-rhombohedral form. Recent developments have enabled us to add materially to our knowledge of the species. The number of specimens obtained is relatively large and in some of them it shows itself in tolerably well-defined crystallized forms. It will be remembered that for our earlier work we had only one or two minute crystals. The habit of most of the crystals now found differs from that before described, fig. 5, the hexagonal form is rather rare and the crystals appear as rectangular tables united in slightly diverging groups, fig. 6.

5.



6.



A closer examination shows that they agree with the same fundamental form before accepted. These crystals are elongated parallel to the orthodiagonal axis, and the basal surfaces are bent and striated in this direction. In addition they show on the edges, sometimes in traces only, the pyramidal planes, which when developed give the hexagonal habit before noted. In addition to the planes a, b, c, x (301), p ($\bar{1}11$) and s ($\bar{2}21$), we have identified also a steep clinodome, n, which has the symbol (051) and a hemi-orthodome, y ($\bar{1}03$). We retain our former axial ratio

$$\dot{a}:\dot{b}:\dot{c}=1{\cdot}73205:1:1{\cdot}19806;\ \beta=61°\ 30'.$$

* By difference.

And the measured and calculated angles are:

	Calculated.	Measured.
$001 \wedge 051 =$	79° 15′	79°
$001 \wedge \bar{1}03 =$	12 50	13–14

Optically we find the crystals as before stated to be biaxial, the optic axes being situated in the clinodiagonal section and the bisectrix nearly normal to the cleavage-face; the double refraction is negative and the axial angle large.

Besides the crystals occasionally appearing in the cavities, and often united in slightly diverging groups with edges parallel to *b* projecting, the mineral occurs foliated to almost massive and granular, the folia, however, usually distinct and often grouped in rosettes or stellate forms.

Dickinsonite is the species about whose composition we felt most doubt when we first published. The material then in hand was very scanty and not entirely pure, and although excellent analyses were made by Penfield, their interpretation was a matter of some doubt because of admixture of more or

DICKINSONITE, BRANCHVILLE.

Analysis of first sample.

Sp. Gr. 3·143.

	I.	II.	Mean.					
P_2O_5	39·57	----	39·57	÷ 142	= ·279			=1·00=1
FeO	----	13·25	13·25	÷ 72	= ·184			
MnO	31·74	31·42	31·58	÷ 71	= ·445			
CaO	2·15	----	2·15	÷ 56	= ·039			
MgO	trace					·814		=2·92=3
Na_2O	7·47	7·44	7·46	÷ 62	= ·124			
K_2O	1·49	1·55	1·52	÷ 94·2	= ·017			
Li_2O	0·20	0·14	0·17	÷ 34	= ·005			
H_2O	1·66	1·65	1·65	÷ 18	= ·094			=0·34=⅓
Quartz	2·58	2·58	2·58					
			99·93					

Analysis of second sample.

	I.	II.	Mean.					
P_2O_5	40·89	----	40·89	÷ 142	= ·288			=1·00=1
FeO	12·96	----	12·96	÷ 72	= ·180			
MnO	31·83	----	31·83	÷ 71	= ·448			
CaO	2·09	----	2·09	÷ 56	= ·038			
MgO	none	----				·811		=2·82=3
Na_2O	----	7·37	7·37	÷ 62	= ·120			
K_2O	----	1·80	1·80	÷ 94·2	= ·019			
Li_2O	----	0·22	0·22	÷ 34	= ·006			
H_2O	1·64	1·62	1·63	÷ 18	= ·092			=0·32=⅓
Quartz	0·85	0·79	0·82					
			99·61					

less eosphorite as well as quartz. Two independent sets of new analyses have been made by Professor Wells. The material for the first was picked with great care, but in order to

remove all question as to whether the results gave the true composition of the mineral, a second and independent analysis was made. For this the very best material was selected and after being separated was minutely examined microscopically to make sure of its purity. The results as will be seen are identical with those of the first.

The two samples were picked from separate specimens and the material was apparently very pure. Unusual care was taken in picking the second sample and its purity is indicated by the small amount of quartz present.

The formula indicated by both the analyses is $3RO \cdot P_2O_5, \frac{1}{3}H_2O$ or $R_3(PO_4)_2 + \frac{1}{3}H_2O$ where R = Mn, Fe, Ca, Na_2, K_2 and Li_2. There is no simple ratio between the alkalies and the remaining bases. The results vary considerably from those of Penfield in his original analysis. This is undoubtedly due to the fact that the present material was much purer than that analyzed by him. Penfield found about 14 per cent CaO, (probably due to admixed fairfieldite) only about 6 per cent of alkalies and 3·87 per cent of H_2O. The formula which he arrived at, however, is confirmed except in the amount of H_2O. It will be seen that the composition now established is essentially the same with that deduced for fillowite on the basis of Penfield's original analysis.

Fillowite.

The fact just stated, that our former formula for fillowite is the same as that now obtained for dickinsonite, has made us very anxious to prove that our early results were trustworthy, especially since the material in hand at the time of our first investigation was very scanty. Unfortunately, among the large number of specimens recently obtained from Branchville, we have not succeeded in finding a trace of this mineral. We have been forced consequently to revert to the few original specimens still in hand. The best of these we gave to Mr. Wells, and from it he picked out about 0·75 gram, in the homogeneity of which he had entire confidence. A new analysis of this has been made by him with the following results; for comparison we quote the original analysis by Penfield.

		Ratio.			Analysis (1878) Penfield.
P_2O_5	39·68	÷ 142 = ·279		1·	39·10
FeO	9·69	÷ 72 = ·135	·847	3·04	9·33
MnO	39·58	÷ 71 = ·557			39·42
CaO	3·63	÷ 56 = ·065			4·08
Na_2O	5·44	÷ 62 = ·088			5·74
Li_2O	0·07	÷ 30 = ·002			0·06
H_2O	1·58	÷ 18 = ·088		0·31	1·66
Quartz	1·02				0·88
	100·69				100·27

It will be seen that the two analyses agree throughout and the formula, is the same, viz: $R_3P_2O_8+\frac{1}{3}H_2O$. As noted above it is identical with that of dickinsonite, although the latter species contains more alkalies and less manganese. The two species are then essentially dimorphous forms of the same compound, and the relation between them is made all the more interesting in that with the striking differences in physical characters, there is yet an obvious relation in form. Dickinsonite is monoclinic with marked pseudo-rhombohedral symmetry and of fillowite the same is true as we have proved by a reëxamination of fragments parallel to the distinct but interrupted basal cleavage. Moreover the dimensions of the forms show a close relation, thus we have:

	Dickinsonite.	Fillowite.
$100 \wedge 001 =$	61° 30′	58° 31′
$001 \wedge \bar{2}21 =$	61 8	58 40
$00\bar{1} \wedge \bar{2}21 =$	61 8	58 40

We have then in these two species an example of a very close and interesting case of dimorphism. The suggestion that the two could be regarded as independent forms of the same mineral differing in habit and state of aggregation could not possibly be made by one who had seen and examined the specimens. We have still hope that in future explorations at Branchville we may find a new supply of this rare and interesting species, named in honor of our good friend, Mr. A. N. Fillow.

Art. XXVII.—*A simple Interference Experiment;* by Albert A. Michelson.

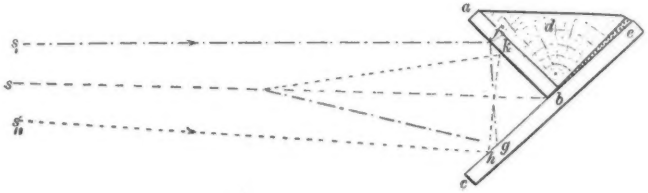
There is probably no experiment connected with the wave-theory of light of greater fundamental importance than the justly celebrated one known as "Fresnel's mirror experiment," and accordingly many find it necessary to repeat the experiment for their own edification or for class demonstration.

Without the use of rather elaborate and costly apparatus even skilled experimenters find some difficulty in producing the desired effect—the interference of two pencils of light as manifested by the appearance of colored fringes on a screen, or in the focus of an observing lens; and unskilled observers find it almost impossible, even with these aids. Even when produced under the most favorable conditions the phenomenon is complicated and often much obscured by diffraction effects.

A very considerable improvement is effected by the substitution of Fresnel's "bi-prism," though in this case one of the chief points of interest is lost; namely, the change of breadth of the bands with alteration of angle. The phenomenon is also complicated by the dispersion of the glass.

The following method has the advantage of being easily within the reach of even unskilled persons, and of giving the required result in all its purity.

Fasten a piece of plane glass *ab*, fig. 1, (selected plate glass will answer, though sextant glass is much better) to a right angled prism of wood *d*; then press *d* against a second piece



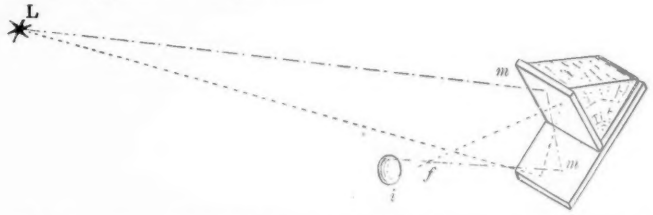
of plane glass *ce* by means of a little soft wax, so that the angle *abc* is a little less than a right angle. If the light from a distant electric arc lamp be allowed to fall on the glasses (which should be silvered on the front surfaces) two rays $s_{,}$ $s_{,,}$ starting in the same phase, after reflections at *f*, *g* and *h*, *k*, respectively, will meet somewhere in the line *bs* in the same phase, the two paths being exactly equal.* Accordingly this line is the locus of the central bright fringe and the system of fringes may readily be observed through a lens of about an inch focal length whose axis is anywhere along this line.

The figure is drawn for clearness in the vertical plane containing the source, and if the intersection of the two surfaces (projected at *b*) were at right angles with *sb* it would be necessary to deflect part of the light to one side by a transparent mirror. But the appearance of the fringes is in no wise changed if the apparatus be rotated through a horizontal angle *a*. The line *bs* is then rotated through $2a$, and there is no difficulty in observing the fringes directly.

It will be noted that no adjustments whatever are necessary. All that is required is that the surfaces be fairly true and the angle slightly less than 90°. This last condition can be readily fulfilled by making the two images of a distant object nearly coincide.

*This is true whether the surfaces form equal angles with *sb* or not.

The following may serve as a guide to the general disposition of the apparatus. Fig. 2.



L is the arc lamp (if provided with a shade the latter should be transparent) *mm*, the two mirrors, *f* the fringes in the focus of the lens *l*, the eye being at an equal distance on the other side of the lens, *Lm* may be 100 meters and *mf* one meter or more.

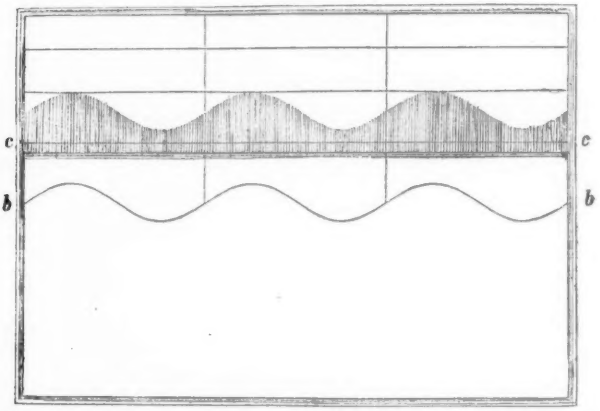
The fringes under these conditions appear as a series of fine lines parallel to the intersection of the surfaces *ab* and *bc*.

If the source be distant and the angle between the mirrors, $90-a$, and the wave length, λ, then it may readily be shown that the width of the fringes is $\lambda/4a$.

ART. XXVIII.—*An Improved Wave Apparatus;* by JOHN T. STODDARD.

THE apparatus shown in the cuts was made several years ago for the purpose of demonstrating to my classes the formation

1.

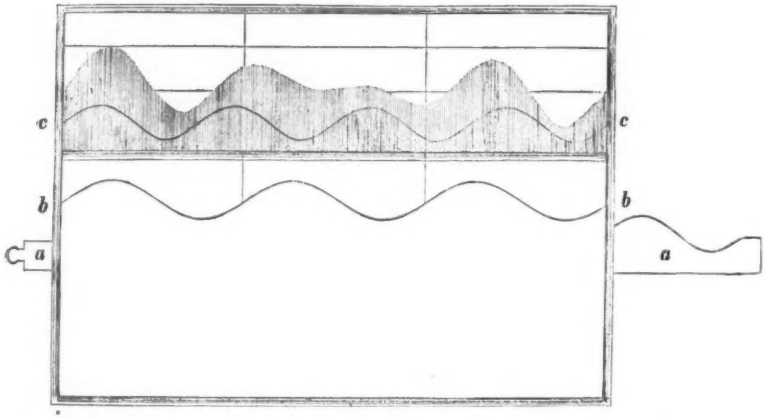


of the compound curves representing the combination of two simple sound waves. It has answered its purpose so well that a brief description may be of interest.

The apparatus consists of a frame of white wood, holding some 270 ebony strips whose tops are trimmed to a sinusoidal form (fig. 1). The strips are 11^{mm} wide, about 4^{mm} thick and from 23 to 31^{cm} long. They are supported on a straight edge projecting 5^{mm} from the back of the frame. Three simple waves having a wave-length of 36^{cm} and an amplitude of 4^{cm} are represented. Vertical white lines mark off the single wave-lengths, a line is drawn on the strips parallel to the edge on which they rest, and the "fundamental" is reproduced in the parallel curve drawn on the front board of the apparatus.

Wave forms cut out of thin board can be introduced below the strips (*aa*, fig. 2), through a slit in the side of the frame, and raised by a simple arrangement at the back to a height which is sufficient to lift the strips from their supporting edge. This

2.



done, the tops of the strips assume the form of the combination curve, while the white line on the strips reproduces the sinusoid on which they rest. As the fundamental is shown on the front board below, one can compare at leisure the component curves and their resultant. The considerable wave-length and amplitude of the fundamental as well as the thinness of the ebony strips render the combination curves fairly smooth. Since three waves of the fundamental are given, it is possible to produce a complete period of the curve representing the interval of the fourth [3 : 4], and one or more periods of all intervals expressed by simpler ratios. The effect of difference of phase is readily demonstrated, the straight line representing the "interference" of two elementary tones of the same pitch and intensity being sharply produced.

Smith College, February, 1890.

ART. XXIX.—*On a recent Rock-Flexure;* by FRANK CRAMER.

THE Combined Locks pulp mill, located on the Lower Fox River, about six miles northeast of Appleton, Wis., is a long, low stone building (about 40 by 248 feet), and set below a head of seventeen feet of water. The direction of its long axis is northwest and southeast. The river flows at right angles to this axis until it passes the end of the mill, and immediately turns east and flows to a point a short distance beyond the mill, where it turns to the north. At about eight o'clock on the morning of the 7th of September, 1889, an accident involving considerable damage happened to this mill.

A solid cement pier, 14 feet through at the top and 16 feet through at the bottom, forms the end of the great dam and the river-end wall of the mill as far as the eaves. Upon this, at its inner edge, is set a two-foot wall which supports the shed roof of the mill. This solid stone pier (P, fig. 1) was cracked from side to side and from top to bottom, and the nearly perpendicular crack gaped between one and two inches at the top and almost none at the bottom. The northeast (down-river)

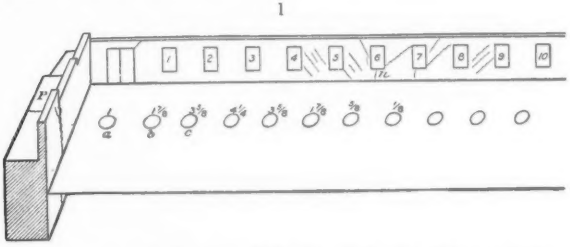


Fig. 1. Diagram showing N.W. end wall and N.E. side wall of mill, with floor in position; other walls and roof omitted. P, cement pier, *a*, *b*, *c*, etc., pulp-grinders, 1, 2, 3, etc., windows. Total length of building, 248 feet.

wall of the mill, running at right angles to the pier, was broken by a symmetrical set of cracks which indicate that the line of disturbance passed under this wall 94 feet from the pier. At this distance there is a perpendicular crack under the sixth window (*n*, fig. 1) One or two smaller cracks run parallel with it. On each side of this crack there are a number of cracks inclined at an angle of 45 degrees, their lower ends directed toward this perpendicular crack. The cracks on the two sides are nearly equal in number, at nearly equal distances from each other, and mar the wall to a distance of about 30 feet each side of the sixth window.

The mill contains 18 or 20 large and heavy pulp grinders, each machine employing two water wheels. These grinders were set in a row, extending through the whole length of the mill about midway between the long walls; and they were all set at exactly the same level. After the accident, the first machine (*a*, fig. 1), next the cement pier, stood an inch above the level of the long row of undisturbed machines in the southeast end of the mill; the second (*b*) had been raised $1\frac{7}{8}$ inches, the third $3\frac{5}{8}$ inches, the fourth $4\frac{1}{4}$ inches, the fifth $3\frac{5}{8}$ inches, the sixth $1\frac{7}{8}$ inches, the seventh $\frac{5}{8}$ of an inch and the eighth $\frac{1}{8}$ of an inch. The set of figures indicating the amounts to which the first eight machines were lifted, is as symmetrical as the set of cracks in the northeast wall; and the fourth machine, which is lifted most, lies in a straight line with the perpendicular crack in the northeast wall and the gaping crack in the pier. The axis of the disturbance passed in a straight line under the mill, diagonally across the north corner. Its direction is nearly northwest and southeast, and parallel with the course of the river between the two bends.

The character of the disturbances and their intimate connection compel the conclusion that they were all produced by a single force. The crack in the cement pier alone might have been produced by the sagging of its lower end; but the application of the simple laws of force to the set of cracks in the northeast wall, proves that the force that produced them acted perpendicularly upward. The inclined cracks need only be extended to form two sides of the parallelogram of forces, and the perpendicular crack becomes the diagonal that indicates the direction of the force, the components of which produced the inclined cracks. To assure himself beyond a doubt that the mill had not given way, Mr. O'Keefe, the gentleman who had charge of its erection, ran the levels again from the bench-mark that was used to secure those levels when the mill was built, and found that nothing in the whole mill was below the level at which it had been placed. A bulge was formed in the floor, and its axis connected the cracks in the pier and the northeast wall; and there is a similar bulge in the roof. The cracks, the figures indicating the distances to which the machines were raised, and the other facts mentioned prove beyond a doubt that the axis of disturbance was an axis of uplift; and that the damage was done by the formation of a nearly symmetrical ridge in the bed-rock. The mill was built on the Galena limestone, which forms the bed of the Lower Fox River at that point. The uppermost layer, on which the walls and piers were set, is two and a half feet thick, and dips to the southeast one foot in two hundred and forty-eight. This layer was nowhere broken and everywhere nearly

plane when the foundations were laid. An unsuccessful attempt was made to examine this layer after the accident by means of a protected electric light. But by careful sounding it was found that this uppermost stratum is no longer plane. Along the inside of the cement pier opposite the crack, the water is not so deep by a whole foot as it is in the neighboring parts of the tail-race; but from this point it grows gradually deeper in both directions. This ridge (*c*, fig. 2), can be traced, but not so clearly, diagonally across to the northeast wall, and its axis is the same as that of the disturbances above. Although there was no evidence of a general crushing, irregular, thin, freshly broken pieces splintered from the thick upper layer were brought up by the man who was sent into the water soon after the accident to examine the rock bottom.

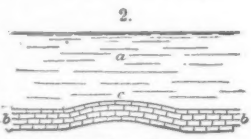


Fig. 2. Section of ridge: *a*, water; *bb*, limestone.

Under the floor of the mill there is a row of iron beams that supplement the stone piers that support the floor and machines. The beams that stand on the ridge are bent (*d*, fig. 3); while one of them, in the deeper water just beyond the ridge, is not only not bent but stands straight and loose in the water (*e*, fig. 3). About 250 feet from the mill there is a new artesian well 225 feet deep. It was flowing at the time of the accident, but not more than three minutes afterward it had stopped and did not start again until several weeks later, when the pipe was given a few blows at its upper end. It then began to deliver water again, but in diminished quantity. Edwards and Orbison, the civil engineers, report that when they built the dam that furnishes the power for the mill, a year ago, they found in the river bed two lines of fracture and crushed rock, and that these lines of fracture in the bed rock are parallel with the axis of the recent disturbances.

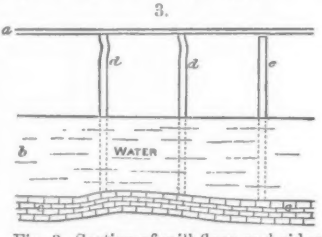


Fig. 3. Section of mill floor and ridge, at right angles to fig. 2: *a*, floor; *c*, limestone; *d*, *d*, *e*, iron pillars.

The character of the cracks in the walls, the fact that the first eight machines, which lie between the breaks in the pier and the northeast wall, are lifted above the level at which they were set, the distances to which those machines were lifted, the bulging of the floor and roof, the ridge in the rock under the mill, the condition of the iron supports under the floor, and the fact that nothing in the mill is below the level at

which it was placed when the mill was built, all point to the same cause. These different lines of evidence are inseparably connected, and taken together amount to a demonstration that the rock under the mill suffered an uplift. The effect on the artesian well proves that the area of disturbance was not confined to the mill; and the parallel fractures out in the river bed show that similar movements have occurred before. The irresistible conclusion is that a movement in the rock was produced by lateral thrust under the very eyes of men.

There can be little doubt that the building of the mill provided the occasion for the movement in the rock. Not only was a great mass of water held up by the new dam, and considerable earth removed in the building of the mill, but in getting out stone for the dam and mill two quarries, each several feet deep, were made in the river bed, one above the dam and the other below the mill. The axis of the disturbances in and under the mill runs from one quarry to the other; and this fact indicates that the break occurred along a line whose weakness was at least partly determined by recent changes.

The Fox River Valley is an almost perfectly level clay plain, cut by deep ravines that run back to varying distances from the river and form the drainage system of the plain. The river has cut its way through the clay and flows on a rock bottom between banks from 60 to 90 feet high. The rock underlying the plain is therefore subjected to a very great and uniform pressure, over an area extending back several miles from the river. The river makes two bends at the point where the mill is located, and the two lines of fracture and crushed rock out in the river, and the line of disturbance in and under the mill are parallel with each other and with the course of the river between the two bends. This parallelism is suggestive, and would be in harmony with the theory that the phenomena were due to lateral pressure in the river-bed induced by pressure of the overlying clay on the adjacent rock. But other phenomena, which have been observed in the neighborhood, preclude the adoption of this theory as an explanation.

At Kaukauna, about two miles down the river from the Combined Locks, Col. H. A. Frambach built a paper mill some time ago. The work of cutting a tail-race in the rock was facilitated by the presence of two joints 30 feet apart. These joints, whose direction was nearly at right angles to the course of the river, converged slightly shoreward and passed downward to an unknown depth. The perpendicular faces were in close contact in both seams; and the strata between the two seams were slightly bowed up in the middle (*a*, fig. 4).

Although the layers were still in position and presented smooth joint faces, the rock, for a distance of about two feet back from both faces of both seams, was splintered by a large number of small fractures parallel to the plane of bedding (*bb*, fig. 4). The faces of these fractures, like those of the joints, were rusty from the decomposition of pyrite. When this part of the rock was broken with a hammer, at the time the layers between the joints were removed, the hammer rebounded as usual when the rock was struck from one direction, but failed to rebound when the rock was struck at right angles to that direction. When it broke it shivered into small pieces.

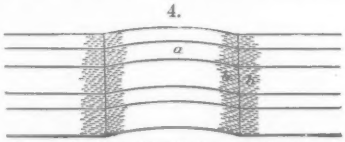


Fig. 4. Section of anticlinal at Kaukauna, Wis.

Evidently a steady and long-continued pressure was brought to bear on the faces of the joints until the layers between them were bowed up and the ends had undergone the preliminary fracturing. And the pressure ceased or the rock was removed just before the crisis came; everything was ready for the production of another "line of fracture and crushed rock." If this is the explanation of the condition of the rock along and between the joints, the theory of pressure of superincumbent mass is inapplicable, for the axis of the disturbances in this case is at right angles to what the theory calls for. But this axis is parallel with the axes of the fractures and folds at the Combined Locks. The two sets of phenomena are less than two miles apart, and the case at Kaukauna seems to be simply a stage through which the rock at the Combined Locks had already passed. They are so intimately connected that a common cause for all of them must be sought. The movements were without doubt all produced by slowly applied and long continued lateral pressure. But if the movements were superficial, as there seems to be some reason for believing, a superficial cause must be sought.

It would be difficult to assign a cause from the study of these cases alone; but it seems reasonable to class them with similar ones observed in other parts of the country. Mr. G. K. Gilbert has propounded a suggestive theory in explanation of phenomena in many respects similar to those presented here.* He believes that sufficient lateral pressure to account for them has been developed in post-glacial times, from the expansion of the superficial strata resulting from the rise in temperature after the disappearance of the ice. This theory has still to be

* See this Journal, vol. xxxii, p. 324; and Proceedings of A. A. A. S., 35th meeting, p. 227.

tested by the answer to the question whether similar phenomena occur outside of the area of glaciation. A negative answer would form a strong support to Mr. Gilbert's theory; and an affirmative would compel search for a more general cause or a distinct one.

Lawrence University.

ART. XXX.—*On the Origin of the Rock Pressure of the Natural Gas of the Trenton Limestone of Ohio and Indiana;* by EDWARD ORTON.

DURING the last five years, there has been developed within six counties of northwestern Ohio, the most important single source of petroleum now known in the United States. During the same time, within the same territory and from the same geological horizon, several separate gas fields of extraordinary vigor and volume have also been brought to light. Following these surprising developments in Ohio, similar discoveries of gas have been made in the contiguous districts of northeastern and central Indiana. The new gas field of this last-named State, is by far the largest continuous gas field known in the world, its original area being not less than 2000 square miles.

The stratum which has yielded these remarkable supplies is the Trenton Limestone, one of the best known elements in the geological scale of North America. Although some phases of its outcrops had long been recognized as petroliferous, no one was prepared for its present enormous production. From single wells, $5\frac{5}{8}$ inches in diameter, 5000 barrels of oil have flowed in a day, and to at least one well a total production of 200,000 bbls. is already credited. The gas wells of the formation are equally prolific. The maximum production thus far has been recently reached in an outflow of 33,000,000 cubic feet a day from a single well. A score of wells can be named, each of which exceeds in its daily flow 10,000,000 cubic feet of gas.

It is well known that the oil market of the country is in no sense an open market in which prices can freely adjust themselves to values. The severest possible repression has been imposed upon the production of the Trenton limestone, by fixing and holding the price of the oil derived from it at 15 cents a barrel, but the inherent vitality of the new source is shown in the fact that even at this rate more than 10,000,000 barrels were brought to the surface in 1889. Natural gas derived from the same formation is now furnishing all of the fuel and much of the artificial light that is used by a population of at least 500,000 people within the districts named

above, while an extraordinary volume of manufactures has been established on the new source of power.

The exploitation, upon which the remarkable developments above indicated are based, has furnished better opportunities in some respects for studying the phenomena and deducing the laws of the accumulation of petroleum and gas than any other American field has supplied. In the first place, the surface of the country in which the drilling has gone forward is so nearly level that all of the wells can be easily referred to a common base, as for example, to mean tide; in the second place, the series of strata penetrated by the drill is so uniform and so well marked that sharp and accurate determinations of all the important facts of stratigraphy are possible, and in the third place, the facts of structure are free from all complications, so that the effects due to them can be clearly and readily followed.

But a single one of the laws of the production of gas and oil as brought to light by this recent experience will be considered in the present paper, that, namely, pertaining to the *rock pressure* of gas; but before taking up this subject, a few preliminary statements, involving some of the laws already recognized, are required.

Preliminary Statements.

1. The gas and oil of the Trenton limestone are held in porous portions of the stratum. Neither caves nor fissures have been found by the drill and none are necessary.

2. The porosity of the limestone is due to the dolomitization which it has undergone. The portions of the stratum thus replaced seem to have been originally crinoidal limestone of a good degree of purity. The spaces left by imperfectly interlocking crystals give the rock great storage capacity, as great probably as the coarsest sandstones possess.

3. The porous beds are distributed through the uppermost portions of the stratum. None have been found as low as 100 feet below the surface, and almost all occur at less than half this depth. Several consecutive beds of dolomite, separated by ordinary and generally impure limestone, are occasionally found in the section. These petroliferous beds commonly range from seven to ten feet in thickness: they rarely rise to fifteen feet. Without dolomite in the Trenton limestone there is no petroleum. The dolomitized regions of the Trenton limestone are exceptional. They appear to extend from central Ohio northward through Michigan and they certainly extend westward through Indiana. To the south and east of these regions, the Trenton limestone lacks this character and is unproductive as to gas and oil.

4. The gas and oil are separated in every division of the field where both occur by lines of geographical level. Proper relief of the porous rock in the shape of arches or terraces is indispensable to gas fields and oil fields. The more pronounced the forms and the amount of the relief, the greater the accumulation.

5. Salt water or bittern is invariably found at a depth, constant for each subdivision of the field, in the lower levels of the porous rock, constituting a dead line for the oil and gas. The water is directly in contact with the oil or in the absence of oil, with the gas that is held in the arches or terraces, as is proved by the behavior of wells on the margins of the field. It is highly mineralized, having a specific gravity of 1·1.

6. When a well is drilled outside the dead line, the salt water rises more or less promptly as soon as the porous bed of the Trenton is penetrated. These salt water tracts are very extensive as compared with the areas of gas and oil, occupying hundreds of square miles to one of the former.

7. The height to which the salt water rises in the various portions of the new gas and oil fields, appears to be nearly constant. It reaches an elevation of about 600 feet above tide. If the elevation of the surface is less than 600 feet, as in portions of the Wabash Valley, the salt water flows from the well mouth.

8. The rise of the salt water to the level named is unquestionably artesian in origin. It implies a head of water, established through continuously porous rock, from some more or less distant outcrop. The fact that the outcrops of the Trenton limestone on the shores of Lakes Superior and Huron are dolomitic and consequently porous, and that they are also about 600 feet above tide, suggests this region as the source of the pressure which is shown in the ascent of the salt water in the gas and oil fields. The Trenton limestone is dolomitic as far as it has been followed under the surface of the State of Michigan, both southward from Lake Superior and northward from the Ohio boundary, the facts as to the latter being obtained by the drill.

Rock Pressure.

By the rock-pressure of gas is meant the pressure in a well which is locked in so that no gas can escape. The tubing of the well becomes in this way a part of the reservoir and shares its pressure. This rock pressure varies greatly in different fields and to a less extent in different wells of the same field. It sometimes reaches the enormous figures of 800, 900, or even 1000 lbs. per square inch. Pressures of 400 to 600 pounds to the square inch are not unusual. The phenomena connected

with the escape of gas from a high pressure well are among the most startling in the whole range of mining engineering operations.

There is generally a rough relation between the depth of the well and its rock pressure. The deeper the well, the greater the pressure to be expected, but this relation is by no means constant. Wells of the same depth below the surface may vary widely in rock pressure.

It is the original rock pressure which is needed in these inquiries, and this can be obtained at but one date in the development of a field, and that is at the very opening. Reduction of pressure speedily follows exploitation, and goes forward more or less rapidly as the development proceeds. When a field is locked in, however, after having been opened, there is a tendency to regain the original pressure. The pressure falls through considerable areas at the same time when drainage of gas is going on from any point within them. The rock pressure is a factor of great importance in every gas field. By it, the distance to which the gas can be sent to market, the size of the tubing employed and also the size and strength of the pipe lines are all to be determined.

To what is this rock pressure due? Three answers have been proposed, viz: (1) it is due to the weight of the rock that overlies the reservoir; (2) it is due to the expansive nature of the gas itself; (3) it is due to the pressure of the salt water column which holds joint occupation with it of the porous rock. The facts derived from the new fields demonstrate the truth of the last answer, so far at least as Trenton limestone gas is concerned.

A column of salt water, one square inch in section, one foot in height, and having a specific gravity of 1·1 weighs (and will consequently exert a pressure of) about ·476 pounds avoirdupois.

Knowing as we do the height to which the salt water rises in the Ohio and Indiana gas fields, when the porous rock containing it is reached by the drill, viz: 600 feet above tide, we find in this figure an element that we can employ in every subdivision of the field. If the gas is found at sea-level, it will have upon it a weight of $600 \times \cdot 476$ lbs In other words, its rock pressure should be 286 lbs. If the gas is found *above* sea-level, its rock pressure should be reduced in proportion to the reduction of the water column; if found *below* sea-level, its pressure should be correspondingly increased.

The facts derived from the development of the new fields furnish data by which the validity of the explanation above given can be tested.

At Muncie, Indiana, the gas was found in the first wells at

very nearly sea-level. At Marion, Indiana, in well No. 3, the gas was struck at 78 feet below tide. In the Dwyer Well, St. Henry's, Ohio, it was found 200 feet below tide; at Findlay, in the Pioneer Well, at 336 feet below; at the Godsend Well, Wood County, at 395 feet below; at Upper Sandusky, in City Well, No. 1, at 478 feet below; and in the Loomis Well of Tiffin, at 747 feet below tide. The rock pressures, therefore, of these several wells should be found by multiplying the number representing in feet the entire length of the water column by which the gas is compressed in each well by ·476 lbs. The lengths of the effective columns in the several wells above named are as follows: 600, 678, 800, 936, 1078 and 1347 feet. The results of the calculations on the basis above indicated, are shown in the following table, in which also other data as to the wells, including their first recorded pressures are given.

	Location of wells.	Depth to Trenton limestone.	Relation of gas rock to sea-level.	First recorded pressure.	Calculated pressure on basis indicated above.	Remarks.
1	Muncie, Ind,	950 ft.	at sea-level	280 to 290 lbs.	286 lbs.= 600 × ·476 lbs.	Figures as to wells are approximate.
2	Marion, Ind., Well, No. 3,	870 ft.	78 ft. be'ow	323 lbs.	323 lbs.= 678 × ·476 lbs.	
3	St. Henry's, O., Dwyer Well,	1156 ft.	200 ft. bel'w	375 lbs.	381 lbs.= 800 × ·476 lbs.	Pressure first noted several months after completion of well.
4	Findlay, O., Pioneer Well,	1096 ft.	336 ft. bel'w	450 lbs.	445 lbs.= 936 × ·476 lbs.	Pressure reported by driller, perhaps given in round numbers.
5	Wood Co., O., Godsend Well,	1136 ft.	395 ft. bel'w	465 lbs.	474 lbs.= 995 × ·476 lbs.	Pressure not noted at opening of field.
6	Upper Sandusky, City Well, No. 1,	1278 ft.	478 ft. bel'w	515 lbs.	513 lbs.= 1078 × ·476lbs	Pressure reported by gas trustees.
7	Tiffin, O., Loomis Well,	1455 ft.	747 ft. bel'w	600lbs. +	641 lbs.= 1347 × ·476lbs	Gauge read only to 600 lbs.: a considerable excess indicated by it.

The results shown in the preceding table are strictly representative, and no facts from the new fields are known to the writer that militate against the conclusion which these calculations oblige us to adopt, viz: that *the rock pressure of the gas of the Trenton limestone is due to the pressure of a water column under which it is held in the arches of the rocks.* While this explanation of the rock pressure of gas is here applied only to the new fields of Ohio and Indiana, it seems probable that it is applicable to all gas fields.

Columbus, Ohio.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Lowering of the Freezing point of Metals by the addition of other Metals.*—Heycock and Neville have investigated the lowering of the solidifying point of a metal which takes place when a small quantity of another metal is dissolved in it in the liquid state. In the first experiments, a number of units of mass corresponding to the atomic mass of each of several metals was dissolved in one hundred atomic masses (11800 units of mass) of melted tin, and the temperature of solidification noted. The difference between this and the solidifying point of the pure metal is called the atomic fall. For Na, this was found to be 2·5°; for Al 1·34; for Cu 2·47. for Zn 2·53; for Ag 2·67; for Cd 2·16; for Sb a rise of 2·3; for Au 2·80; for Hg 2·3; for Tl 2·6; for Pb 2·6; and for Bi 2·10. The next series of experiments was made with sodium as the solvent; a cylinder of cast iron 6 to 8 inches high and 5 inches in diameter being used, in the axis of which was a hole 1 to 2 inches in diameter and 4 inches deep, within which worked an annular stirrer. This cylinder was heated by a gas burner, being wrapped with asbestus cloth so that it cooled at the rate of only a degree in two minutes. The temperatures were noted on a thermometer having an arbitrary millimeter scale and reading to nearly one-hundreth of a degree. From 20 to 30 grams of sodium were melted in this cylinder and covered with a layer of paraffin. The whole was then raised to the boiling point of the paraffin, the metal added in the state of fine division, the mixture well stirred and the whole allowed to cool. The thermometer fell steadily to a certain point, then rose suddenly through one or two degrees where it remained stationary for several seconds, sometimes a minute. The highest temperature reached during this surfusion was taken to be the freezing temperature of the alloy. The first point noted was that sodium even at 250° dissolved only a few metals; Au, Li, K, Hg, Tl and In dissolving freely, Pb and Cd sparingly, while Zn, Sn, Al, Mg, Ag, Pt and Fe did not dissolve in appreciable quantities. On placing a clean piece of the sodium alloy in absolute alcohol, the dissolved metal separated as a fine powder generally crystalline. In the case of gold, 100 atomic units of mass of sodium were found to keep in solution 3·5 atomic units of mass of this metal, forming a saturated solution behaving like a weak solution of sodium chloride in water as observed by Guthrie. The atomic fall per atomic mass-unit for this alloy was 4·578°, the temperature of solidification being remarkably constant at 81·92°. On treating with alcohol the gold separates in fine needles. An alloy obtained by diluting this saturated alloy with sodium, gave on analysis gold 15, sodium 85·03 per cent and had a density of 1·152; the calculated density being 1·141. Thus showing that the density of the alloy is a mean of that of its constituents and

that it is a mixture; although no separation of its constituents took place on keeping a column of it in fusion for 48 hours, the composition of the alloy being substantially the same throughout. With thallium, 4·384 atomic units of mass lowered the solidifying point of 100 atomic mass-units of sodium nearly twenty degrees; being a fall for one atomic unit of mass of 4·468 degrees. The point of saturation was not determined. In the case of mercury, although there is a considerable evolution of heat and light on mixing it with the sodium, yet the atomic falls produced by the successive additions do not indicate the formation of a definite compound as would be expected. The addition of 3·228 atomic mass-units of mercury to 100 atomic units of sodium lowered the solidifying point 14·12°; being 4·374° for each atomic mass-unit. When thallium and mercury were both added to sodium, while the atomic fall due to the Hg was 4·4 and that due to the Tl was from 4·09 to 4·27, that produced by both was from 4·16 to 4·26, substantially the same. At the temperature of 95·43° 3·05 per cent cadmium was found to saturate sodium; this quantity being 0·6475 atomic units of mass to 100 atomic mass-units of sodium; the atomic fall resulting being 3·173°. The addition of 3·455 atomic mass-units of potassium to 100 atomic mass-units of sodium lowered the freezing point 11·56°; corresponding to an atomic fall of 3·345°. In the case of lithium the atomic fall was 1·11°, in that of lead 4·6°, and in that of indium 3·49, at the saturating point.—*J. Chem. Soc.*, lv, 666, November, 1889. G. F. B.

2. *On the Chlorides of Selenium.*—CHABRIE has subjected the chlorides of selenium to investigation and has observed that the tetrachloride may be obtained in large and well formed crystals by heating the ordinary product to 190°–200° in the end of a sealed tube. The vapor density of this chloride could not be determined by Victor Meyer's method at 360°, even in an atmosphere of nitrogen, two molecules of this substance dissociating at this point into one molecule of Se_2Cl_2 and three molecules of chlorine. Selenous chloride, however, is quite stable, distills unchanged at 360° and has a vapor density of 7·95, approximately. With regard to the chemical reactions of the tetrachloride, the author finds that the action of benzene upon it is precisely the same as that which is produced by heating to 360°; the selenium being left in the form of selenous chloride and the chlorine forming chlor-benzene. If, however, the mixture is made in presence of aluminum chloride, the reaction is quite different. So that on treating the resulting solution with water, and fractioning the oily product three substances are obtained: one, boiling at 131°–133°, consisting of monochlor-benzene C_6H_5Cl; a second, passing over, under a pressure of a few millimeters of mercury, at 227°–228° consisting of phenyl selenide $(C_6H_5)_2Se$, and appearing as a yellow oil having a density of 1·45 at 19·60; and a third, boiling under the above reduced pressure at 245°–

250°, and consisting of another new compound having the composition $(C_6H_5)_2Se_2 . C_6H_4Cl$. This last fraction is a red oil having at 19·60 a density of 1·55. On standing it deposits yellow crystals having a powerful odor, which on re-crystallization from alcohol may be obtained in long rhombic prisms. This substance is seleno-phenol $(C_6H_5)SeH$, analogous to thiophenol and mercaptan; and like these bodies its alcoholic solution reacts readily with mercury and silver salts, the latter affording the compound C_6H_5SeAg.—*Bull. Soc. Chem.*, III, ii, 788, Dec., 1889. G. F. B.

3. *On the Production of Sodium carbonate by the Electrolysis of the Chloride.*—A series of experiments by Fogh made at HEMPEL's suggestion, showed that the difficulty in electrolyzing metallic chlorides lay in the fact that whenever the decomposition products were readily soluble, they were in their turn decomposed so soon as they reached a certain limit. If, however, the products of electrolysis were difficultly soluble, no such secondary action took place and all the electric energy was expended on the primary decomposition. Inasmuch as sodium carbonate and hydro-sodium carbonate are difficultly soluble in a saturated solution of sodium chloride, Hempel concluded that by the introduction of carbon dioxide into the apparatus, salt could be directly converted by the current into sodium carbonate and chlorine. The apparatus which he has contrived for this purpose consists of a circular kathode of perforated iron and a similar anode of carbon, having between them a disk of asbestus paper. Outside of each electrode is a ring of porcelain and a disk of glass forming chambers for containing the materials, a glass tube carrying carbon dioxide into the kathode chamber and another carrying the chlorine away from the chamber containing the anode. A lateral tube of considerable size permits the salt to be fed continuously to the anode, the water removed by the crystallized carbonate being replaced through it. An electromotive force of 3·2 volts is required to decompose the salt and one of 2·5 volts to overcome the polarization of the plates; though if both plates are of carbon, the counter electromotive force of polarization is absent. With a current of 1·73 amperes, 0·930 gram of chlorine is produced per hour. So that by the use of a dynamo, 64·5 grams of chlorine and 259·8 of sodium carbonate $Na_2CO_3(H_2O)_{10}$ would be produced per horse-power per hour. The same general idea is the basis of a patent taken by Marx since the author began his experiments; but the mechanical arrangements of Marx's apparatus were bad and the results were not satisfactory.—*Ber. Berl. Chem. Ges.*, xxii, 2475, Oct., 1889. G. F. B.

4. *Barium cobaltite.*—ROUSSEAU has shown that cobalt dioxide possesses acidic properties. If barium chloride mixed with barium oxide be fused in a platinum crucible, and cobaltic oxide Co_2O_3 be added in successive small portions, a crust of barium cobaltite forms on the surface. After cooling and washing with hot water and acetic acid, brilliant black hexagonal laminæ are obtained having the composition $BaCo_2O_5$, which are soluble

in strong hydrochloric acid with evolution of chlorine. If during the heating the superficial layer be continually pressed into the fused mass, the composition of the crystals approaches the formula $BaCoO_3$. At a higher temperature large iridescent black prisms are obtained, having very closely the composition $BaCoO_3$, but containing a trace of barium platinate. The temperature of their formation is between 1000° and 1100°.—*C. R.*, cix, 64; *J. Chem. Soc.*, lvi, 1115, Dec., 1889. G. F. B.

5. *On the Constitution of Dextrose.*—SKRAUP has made experiments on the pentabenzoyl derivative of dextrose and has afforded evidence that the view of Fittig and of Tollens that this sugar may be considered as an ether derived from a hepta-hydric alcohol, and therefore as having the formula

$$OHCH_2[CHOH]_3\overset{O}{\underset{\diagdown\diagup}{CH}}.CH.OH,$$

is correct. The above dextrose derivative is not oxidized by permanganate to pentabenzoyl gluconic acid; and on treatment with phenyl-hydrazine, two dextrose compounds result, one derived from $C_6H_{12}O_6$, the other from $C_6H_{12}O_6.H_2O$.—*J. Chem. Soc.*, lvi, 1136, Dec., 1889. G. F. B.

6. *Electrical Undulations.*—MM. EDOUARD SARASIN and LUCIEN DE LA RIVE in repeating Hertz's work upon this subject have discovered that the oscillatory character of the electrical charge on a wire submitted to induction, instead of being invariable in character like the vibrations of an elastic column submitted to motions of a definite period, depend, on the contrary, upon the resonator employed by Hertz to explore the wire. The phenomena observed by the above mentioned authors is termed multiple resonance. Cornu, on the occasion of the presentation of the communication of the authors of the results of their experiments to the French Academy, remarked in substance as follows. The theory of Hertz depends upon two distinct elements:

(1.) The hypothesis that the spark from a Ruhmkorff coil produces an oscillation of a fixed period, determined by the construction of the exciter.

(2.) Upon the observation of an apparent periodicity in the electrical state of the wire submitted to electrical oscillations. The experiments of MM. Sarasin and de la Rive throw great doubt upon Hertz's work. Since in the expression $\lambda = VT$ in which λ = wave-length, V = velocity of propagation of induction in the wire under examination, T = period of oscillation of the exciter, it is shown that either T is not fixed which is contrary to the fundamental hypothesis, or that V varies with the exploring apparatus, which is absurd, since V should represent the velocity of propagation of induction, a specific constant.—*Comptes Rendus*, Jan. 13, 1890, p. 72. J. T.

7. *Experiments with Hertz's Vibrations.*—Professor G. F. FITZGERALD states that on connecting a delicate galvanometer with a Hertz resonating receiver, every time a spark passed the galvano-

meter was deflected, the direction of deflection changed with the reversal of the primary induction. No satisfactory explanation of this deflection is given. Mr. Trouton, who has worked with Professor Fitzgerald upon the Hertz effect, states that the phenomenon observed by MM. Sarasin and de la Rive was noted by Hertz, "It seems as if a vibrator did not send out a line spectrum," so to speak, but sends out a band spectrum, the center of which is the brightest. The period then, of a vibrator is that belonging to the center of this band. "It is obviously of importance for the central period of the resonator employed to coincide with the velocity of the disturbance, for this is presumably the period given by theory. This is practically done when arranging their relative sizes, so as to obtain greatest intensity." Mr. Trouton does not agree with Cornu in his view of the important bearing of the experiments of MM. Sarasin and de la Rive upon Hertz's work.—*Nature*, Jan. 30, 1890, p. 295. J. T.

8. *Note on the Absolute Viscosity of Solids, Liquids and Gases;* by C. BARUS. (Communicated.)—In case of gases and of mobile liquids, viscosity is expressible in *g/cs* units with facility, and data are available in great number. This is not true for solids, nor even for viscous liquids. Suitably integrating the elementary transpiration equation, I obtained two methods, by which the viscosity (η) of glycerine can be measured in a few minutes, and the viscosity of substances of a pitchy consistency (marine glue) in a few months. Thus I found for glycerine $\eta=5$; for marine glue, $\eta=200\times10^6$; for paraffine, $\eta>2\times10^{11}$. Even marine glue or hard pitch is therefore at least 20 billion times as viscous as water at the same mean atmospheric temperature.

For solids I devised two new methods, one of which is comparative and somewhat crude, the other direct, dynamic and sharp. I found for hard steel, during the first hour after twisting just within the elastic limits, at mean atmospheric temperature, $\eta=10^{17}$ to 6×10^{17}; for soft steel, $\eta=6\times10^{17}$ to 6×10^{18}, under the same conditions. Limits must here be given because solid viscosity, even apart from the material operated on, is essentially a function of time, strain and temperature, of a kind which cannot well be tersely specified. Both viscosity and its rate of increase with time under the same given conditions, are magnitudes which increase together.

With these data in hand I submit the following *g/cs* scale of the *solidity* of the three states of aggregation: I. Gases and vapors, $\eta=10^{-5}$ to ?; II. Andrew's critical state, $\eta=$? to ?; III. Liquids, $\eta=$? to 10^2; IV. Viscous liquids, $\eta=10^2$ to 10^{11}; V. Solids, $\eta=10^{11}$ to 10^{20}. Since for ether at 30°, $\eta=9\times10^{-4}$ and for oxygen at 0°, $\eta=2\times10^{-4}$, it is not improbable that the critical state may be definable by a narrow limit of viscosity. Data are wanting.

The scale proposed indicates the positively astounding range of variation of the chief variable of our material environment,—bearing in mind that throughout the whole of this great interval viscosity nowhere transcends the scope of the senses.

9. *Absolute Measurements in Electricity and Magnetism by* ANDREW GRAY. Second Edition revised and greatly enlarged. 384 pp. 12 mo. London and New York, 1889. (Macmillan & Co.) A first edition of this work was published in 1884, (this Journal, vol. xxvii, 487); since that time the author has issued the first volume of a larger and more exhaustive work on the theory and practice of Absolute Measurements in Electricity and Magnetism, a second volume of which is now in press. Excellent as is this last mentioned work, it does not take the place to the student of the more elementary one which preceded it. It is well therefore that the author has been induced to revise the latter; in its present expanded form the student will find it a most satisfactory guide to the methods of quantitative measurement which form the foundation of modern electricity.

10. *Elementary Lessons in Electricity and Magnetism*, by SILVANUS P. THOMPSON. 456 pp. 12mo. London and New York, 1889. (Macmillan & Co.) The first publication of this admirable little book was noticed in vol. xxiii, of this Journal. Since that time it has been repeatedly revised and the present issue is of the forty-third thousand. No better proof than this remarkable reception is needed of the excellence of the work and of its adaptation to the wants of the particular class of students for whom it was prepared.

II. GEOLOGY AND MINERALOGY.

1. *Sedgwick and Murchison, page* 167.—It is a pleasure to announce that the paper of Murchison published in the Philosophical Magazine for July 1835, is republished in the *American Geologist* for February.

With regard to the Lower Silurian, the term *Cambro-Silurian*, which is used already by the Canadian Survey, might serve, supposing another name needed, if its signification accorded with geological usage. It means, as employed in Canada, a formation that is neither Cambrian nor Silurian, but which lies between the Cambrian and Silurian formations. This is out of harmony with the terms *Permo-Carboniferous, Jura-Trias, Calciferous-Trenton*, and the like; which stand for combinations of the formations indicated, and especially where their separation is at present difficult or impossible. Such terms are too useful in the science to be dispensed with. J. D. D.

2. *The Calciferous Formation in the Champlain Valley.* Notes from a paper presented before the Geological Society of America, at its winter meeting, Dec. 26–28, 1889, by E. BRAINERD and H. M. SEELY.—The region under investigation extends east and west from the flank of the Green Mountains to the Adirondacks, a distance of about twenty miles, and north and south from Phillipsburgh, Canada to Benson, Vt., and Ticonderoga, N. Y., near eighty miles.

In this valley all the formations of the Lower Silurian are represented. On the east the rocks are much metamorphosed; on

the west, part are under the waters of Lake Champlain. The rocks may be best studied along the shores and on the islands of the lake.

The term Calciferous is used in its original signification, and includes all the rocks lying between the Potsdam lying below, and the Chazy above. The boundary lines are at present provisional. The lower is just above the fossiliferous Potsdam, the upper just below a sandstone which is assumed to be the base of the Chazy, one recognized by the Canada survey, and which may possibly correspond to the St. Peters Sandstone of the west.

The Calciferous formation is essentially one of magnesian limestone; it contains, however, pure sandstone, pure limestone, together with mixtures of these, a calciferous sandstone, whence the name.

The rocks have a greater thickness than previously attributed to them, and contain many fossil forms. Subdivisions are made, based upon lithological and faunal characteristics. These are named A, B, C, D and E, and are read from below upwards.

Division A rests upon the uppermost member of the Potsdam. The rock is a dark bluish gray magnesian limestone, mostly massive, more or less siliceous, weathering dark or sometimes with a tinge of yellow. White quartz nodules appear in some of the higher layers, and near the top, large masses of black chert. Thus far no distinguishable fossils have been obtained. It has a thickness of 310 feet.

Division B is marked by the presence of nearly pure reticulated limestone, weathering white, intermingled with light colored dolomite. The bedding is obscure. The pure limestone which occurs near the middle and again at the upper part is like the Birdseye limestone in flinty compactness and fracture. Well-marked fossils are found in B. Thickness, 295 feet.

Division C is sharply separated from B below by a peculiar fine-grained sandstone containing calcareous matter, and which on weathering resembles fine-grained wood. Some of these layers are pierced with worm burrows. Thickness, 350 feet.

Division D is made up of many varying rocks. Blue limestones form the base. Above are magnesian limestones, and sandy limestones, the latter weathering to a rusty rotten stone. Still above are dark magnesian limestone and tough sandstone, sandy limestone weathering into bands, blue limestones with very tough slaty layers which give it a peculiar and characteristic appearance on the exposed edges, pure limestone and sometimes conglomerates. Very fossiliferous. Thickness, 375 feet.

Division E has fine-grained magnesian limestones weathering various tints. Occasionally pure limestone layers occur, and rarely thin layers of slate. The limestones and slates are fossiliferous. Thickness, 470 feet.

For all the five divisions of the formation there is a thickness of 1800 feet.

Sections of the rocks in different localities show great uniformity in characteristics of thickness and lithological structure.

A typical section from which the above measurements were taken is found in Eastern Shoreham, Addison County, Vt. In this section not only are all the strata of the Calciferous seen, but the whole Lower Silurian appears from Potsdam to Utica Slate in a continuous series. This locality was first pointed out by Rev. Augustus Wing, and denominated the "Bascom Ledge." [This Journal, 1877, vol. xiii, p. 343.]

The paleontology of the Calciferous is not complete, though good advance has been made. Division A has not yielded distinguishable fossils. Division B seems to be the horizon of the original *Orthoceras primigenium* of Vanuxem. It contains also the remarkable banded masses which at one time were regarded as concretions and were figured and described as such by Dr. J. H. Steel. [This Journal, June, 1825, vol. ix, pp. 16–19.] Mather, in his N. Y. Report, recognizes their organic origin. Probably the fossil is a Cryptozoon and the form may be known as *Cryptozoon Steeli.*

Division C, besides containing the numerous worm burrows at its base, *Scolithus minutus*, according to Wing, holds some poorly preserved forms of gasteropds and cephalopods.

Division D is rich in fossils. Sponges, brachiopods, gasteropods, cephalopods, trilobites and ostracods appear. The abundant fauna of the Fort Cassin rocks belongs here. Thirty-five genera have been gathered.

Division E, though apparently not so fossiliferous as D, adds new forms, generic as well as specific, and brings the number of Calciferous genera above forty with species numbering from one to ten.

Besides the section referred to at Eastern Shoreham, other exposures have been investigated. One section from the vicinity of Ticonderoga takes in Mt. Independence, Lake Champlain, and the grounds of the old Fort. The rocks at Orwell, Fort Cassin, Charlotte, Providence Island, and Phillipsburgh, Canada, expose a part or the whole of the divisions of the Calciferous.

The series of rocks at Phillipsburgh extend from four to five miles into Vermont. Logan's division A with its three subdivisions, seven hundred feet in thickness [Geol. Canada, p. 844], is lithologically identical with the divisions A, B, and C, respectively of the Calciferous. The fossil *Cryptozoon Steeli* [n. sp.] is seen in the reticulated limestone of A 2, at Phillipsburgh. Similarly the first four of Logan's division B correspond to the later division D of the Calciferous both in lithological character and in fossils. (Geol. Canada, pp. 278, 279.) The beds of the Calciferous sandstone are as peculiar at Phillipsburgh as at Shoreham.

A similar comparison might be made between the Calciferous of Lake Champlain and the 1830 feet of strata on the northwest coast of Newfoundland, (Divisions D to L of Geol. Canada, p. 865, et seq.).

Misapprehensions in regard to some of the rocks of Vermont are to be corrected. Certain slates referred to the Calciferous

belong properly to the Utica Slate. Very little slate has been observed in the Calciferous, and this in the upper part of Division E.

The Birdseye formation is very scantily represented in Vermont. A rock covering a few square rods containing *Phytopsis tubulosum* Hall, is found in Benson. The fine-grained limestones so like the Birdseye in texture must be distributed among the strata below. Part will go to Calciferous B, a part to Calciferous D. Here come the Fort Cassin rocks. Middle Chazy will take a small part; upper Chazy much more. *Calymene multicosta* Hall, with its associated fossils, belongs here in the upper Chazy. The fine-grained limestone which holds this interesting group of fossils is still beneath seventy-five feet of Rhynchonella rock. Above this, if anywhere, the Birdseye should appear.

Attempt is not made to correlate the Calciferous of the Champlain Valley with that of the western States. Rocks of similar Calciferous character appear in the valleys of the Hudson and St. Lawrence, as well as that of the Champlain; suggesting that the same physical conditions of sedimentation and like forms prevailed. The deposits marking the position of an ancient sea beach not far from the borders of the Archæan terrane.

3. *Geological Survey of Canada, Annual Report for the year* 1887–88; ALFRED R. C. SELWYN, Director. Vol. III, New Series, Parts i and ii.—This Report, after a general review of the work and results of the year by Dr. Selwyn, contains first a Report by G. M. Dawson on an exploration of the Yukon District, and an adjacent part of British Columbia, treating of its geography, climate, resources and geology, and, in appendixes, of its vegetation, Indian tribes, zoology, rocks and meteorology. Mr. Dawson states that the Coast Ranges have an interrupted granitoid axis (consisting of granite and granitoid rocks) from Fraser's River northwestward to the 60th parallel, about 900 miles; and that the formations of British Columbia in general continue northwestward, with little variation. West of the Coast Range in the Coast Archipelago near Wrangell, Juneau and Sitka, occur argillites which, as fossils have not yet been detected, may be provisionally classed as Triassic. East and northeast of the Coast Range the rocks are largely Paleozoic. On the Dease, the Frances, and on Tagish Lake, Carboniferous limestone is found containing Fusulina, like that of British Columbia; this rock occurs along a belt of 800 miles or more. Granitic areas occur over this area in two ranges; one from Dease Lake (130° W. and 58½° N.) to 40-mile Creek (141° W. and 64½° N.) and the other east of Frances Lake (129° W. and 61° N.) and Pelly Lakes (129½° W. and 62° N.); The rocks resemble the Archæan granites of the Gold Range of British Columbia. Triassic rocks were found on the Stikine River at Glenora, and Cretaceous and Laramie on the lower part of the Lewes on Lake Labarge and elsewhere. Jade was met with in large masses in the gravels of the Lewes.

Other reports of the two volumes are as follows: A. Bowman on the Mining District of Cariboo; J. B. Tyrrell, on the Duck and Riding Mountains, in N.W. Manitoba; A. C. Lawson, on the rocks of the Rainy Lake region; E. D. Ingall on Mines and Mining on Lake Superior; A. P. Low, on part of the country east of Hudson Bay; R. W. Ells, on the geology of a portion of the Province of Quebec,—a report noticed at length at page 101, by Mr. C. D. Walcott; L. W. Bailey and W. McInnes on portions of northern New Brunswick and adjacent parts of Quebec and Maine; R. Chalmers, on the surface geology of N. E. New Brunswick; G. M. Dawson, on the mineral wealth of British Columbia; E. Coste, Statistical Report on the production, exports, and imports of the Minerals of Canada; G. C. Hoffman, Chemical contributions.

Messrs. Bailey and McInnes illustrate in their report the paleozoic geology of northeastern Maine, and apppear to show that the rocks of this part of Maine in Aroostook Co. are Upper Silurian rather than Devonian, which they are made in the Geological Reports on Maine.

4. *Manual of Palæontology, for the use of Students, with a general Introduction on the principles of Palæontology;* by Henry Alleyne Nicholson, F.G.S., Prof. Nat. Hist. Univ. of Aberdeen, and Richard Lydeker, B.A., F.G.S. 3d edit. rewritten and greatly enlarged. 2 vols. of 1624 pages. Edinburgh and London. (Wm. Blackwood & Sons.)—The title page says, "greatly enlarged;" expressed in figures the enlargement is from 1040 to 1624 pages, or more than one-half; and this increase in size indicates very imperfectly the actual additions in new matter and illustrations. It is, as the authors claim, essentially a new work. The part on the Invertebrates, covering 775 pages, has been prepared by Prof. Nicholson, and that on the Vertebrates, 600 pages, by Mr. Lydekker, the author of reports connected with the Geological Survey of India on the fossil Vertebrates; and about 100 pages on fossil plants are by the joint authors. The classification follows mainly the latest authorities, and the descriptions are full and present a judicious review of recent opinions in cases of doubt, besides having, after each subject, a table of references to publications. We should separate the Trilobites from the Crustaceans, and make some minor modifications; but these are points about which there is reason for difference in judgment. Excellent figures are in profusion, representing often the interior structure as well as exterior forms, and some are from new observations by the author. This manual is the only one of the kind in the English language and will be found of great value by teachers and students in geology or paleontolgy. Prof. Nicholson's personal work in America supplied him with part of his facts, and has enabled him to appreciate and use American sources of information. The volumes are made attractive also by the very liberal style of publication.

5. *Elemente der Paläontologie* bearbeitet von DR. GUSTAV STEINMANN, Ord. Prof. Geol. u. Min. Univ. Freiburg, unter mitwirkung von DR. LUDWIG DÖDERLEIN, Director, Nat. Mus., Strasburg, Privatdocent für Zoologie. 2d Half, pp. 337 to 348, 8vo. Leipzig, 1890. (Wilhelm Engelmann.)—The first part of this important work has been noticed on page 235 of volume xxxvii of this Journal. This *second half* completes the account of the Invertebrates on page 515, and devotes the remaining 333 pages to the Vertebrates. The work is concise in its method, so that its 850 pages cover the whole ground with remarkable completeness. Besides detailed descriptions, tables are introduced to illustrate characteristics of groups, distribution of genera in time, geographical distribution, and also the literature of the different subjects. The illustrations of species and structure are all admirable, and in great numbers; and the publisher has done justice to the fine cuts in the style of printing and the quality of paper. While the figures range over the same groups as in the English work above mentioned the most of them are different, and in this and other ways the two works conveniently supplement one another. They are both excellent, and good companions. In classification there is a similarity. But the Solenhofen Jurassic bird is made by Prof. Steinmann the basis of one of the subdivisions of Reptiles—the Saurura; and the fine figure in the work of the specimen in the Berlin Museum, from the memoir by W. Dames, goes far toward sustaining this reference.

The Trilobites have the same place as in Prof. Nicholson's work, that is, with the Crustaceans, under the name of Palæostraca. The serious objection to this is that the Trilobite and Crustacean lines commence together in the Lower Cambrian and give no evidence of successional connection in their beginning or afterward; they continue separate and unaffiliated to the present time, being represented, as long held, by the modern Limulids, and also, as has been shown by Van Beneden, through the Eurypterids by the spiders. The Crustaceans appear first under two types, the Ostracoid and Caridoid, and continue along each, with small divarications, and with rising grade in the latter until now. The Trilobite line, therefore, had in no part true kinship with that of the Crustacean.

III. BOTANY AND ZOOLOGY.

1. *Manual of the Botany of the Northern United States, including the district east of the Mississippi and north of North Carolina and Tennessee;* by ASA GRAY, late Fisher Professor of Natural History in Harvard University.—Sixth Edition (Revised and extended westward to the 100th meridian); by SERENO WATSON, Curator of the Gray Herbarium, Harvard University, and JOHN M. COULTER, Professor of Botany in Wabash College, assisted by specialists in certain groups. 760 pp. 8vo. With 25

plates, illustrating the Sedges, Grasses, Ferns, etc. New York and Chicago, 1890. (Ivison, Blakeman & Company.)

It is now more than twenty-two years since the fifth edition of Gray's Manual was published. At that time only the first volume of Bentham and Hooker's *Genera Plantarum* had appeared, and Dr. Gray was able to adopt such of their conclusions as pleased him only through the polypetalous orders. The Genera was finished in 1883, and in 1886 Dr. Gray gave his final revision of the Gamopetalous orders of the North American flora. These works and other great advances in Systematic Botany have for several years rendered a new edition of the Manual very desirable, and it is understood that Dr. Gray was hoping to undertake himself the task of preparing it. After his death the labor naturally fell to the lot of Professor Watson, who has availed himself of the assistance of Professor Coulter, the author of the *Manual of the Botany of the Rocky Mountain Region*, and has also had, as the title shows, the aid of specialists in certain groups. The editors have extended the area covered by the work, so as to meet that of Coulter's Manual, and have included an account of the *Hepaticæ*, prepared by Professor Underwood. Aside from these additions, the principal changes are, 1st, the interpolation of such native plants as have been found since 1867 within the territory covered by the Manual, together with the exotics which have since that time gained a foothold, 2d, the entire re-arrangement of the gamopetalous orders after Ericaceæ in accordance with the system given in the *Genera Plantarum*, and a similar re-arrangement of the apetalous and monocotyledonous orders. The *Ilicineæ* are placed among the polypetaleæ; *Diapensiaceæ* replaces *Galacineæ; Plantaginaceæ* stands at the end of gamopetaleæ; *Saururus* is referred to *Piperaceæ*, and the birches and alders constitute a suborder of Cupuliferæ. The old division of the monocotyledonous orders into Spadiceous, Petaloideous and Glumaceous plants is discarded, and the prime distinction is now found in the inferior or superior position of the ovary. These, and other similar changes, were fairly demanded by the advance in the general principles of systematic botany.

The Analytical Key to the Natural Orders of the fifth edition was largely artificial in its character, and occasionally brought near together orders having no very close real affinity. This is replaced in the present edition by a Synopsis in which nearly all the orders follow the same sequence that is observed in the body of the work, the only exception being in the case of the 127th order, *Eriocauleæ*, which for the sake of convenience is placed in the Synopsis at the end of the group headed by *Liliaceæ*, instead of being in its true place as the first of the glumaceous orders. A noticeable improvement is the more general arrangement of the genera of each order, and the species of each genus, in a descending series, from the most highly developed down to the lowest forms. The application of this method is seen in *Polygala*, which now begins with the most showy species, *P. paucifolia*, has the

less showy purple-flowered species next, and ends with the yellow-flowered forms. So again in the genus *Carex*, contributed by Professor Bailey, the large and showy *Physocarpæ* are placed first, and the less highly developed species of the section *Vignea* at the end. In *Hepaticæ*, also, *Frullania* leads off, as being most specialized, and the simpler forms follow in due downward progression, the *Ricciaceæ*, simplest of all Acrogenous plants, closing the series. In each genus only the native species have numbers, and their names are printed in full-faced Roman type; while the names of introduced plants are printed in small capitals, and not numbered. As would of course be expected the whole number of plants described is much greater than in the last edition. Taking only the indigenous phænogams and pteridophytes for comparison, the number recognized in 1867 was 2357; it is now 2753, an increase of nearly 400. The westward extension of the flora described will account for most of this increase. It may be noticed especially in such genera as *Psoralea*, *Dalea*, *Petalostemon* and *Astragalus*, in which there is a considerable increase of species, and in the introduction of *Aplopappus*, *Grindelia*, *Townsendia*, *Orthocarpus*, *Eriogonum*, etc., all genera characteristic of the Rocky Mountain or the Pacific coast floras.

A few more southern plants have now been found north of the Carolinas and Tennessee, and a still smaller number of high northern plants have been lately gathered within our district for the first time. Really new discoveries within the old geographical limits are of course very few:—*Epipactis* takes its place among the Orchids, and in *Clematis*, in *Arabis*, in *Phacelia*, in *Pedicularis*, in *Carex*, and perhaps in a few other genera, an occasional novelty is described. A slight increase is due to the recognition of specific rank in forms not counted as species in former editions, as, for instance, in *Ranunculus* and in *Tilia*.

Some rectification of the names of species and genera, and even of orders, is unavoidable; and the number of such changes is considerable, though far less than one school of botanists would have desired to see. That pretty spring-flower, the Rue-anemone, becomes *Anemonella thalictroides*; what has been called *Thalictrum Cornuti* is now *T. polygamum*; *Ranunculus ambigens* is given in place of *R. alismæfolius* of the old Manual, because the true *R. alismæfolius* is something different; *Buda* is accepted as the first generic name for what was heretofore called *Spergularia*, and similar changes may be found here and there throughout the volume. The preface says:—"In case of question respecting the proper name to be adopted for any species, Dr. Gray's known and expressed views have been followed, it is believed, throughout the work. While reasonable regard has been paid to the claims of priority, the purpose has been to avoid unnecessary changes, in the belief that such changes are in most cases an unmitigated evil." Dr. Gray's views are certainly well understood, and are known to have been in accord with the teachings and the examples of Robert Brown, Bentham, the Hookers and other great

masters of scientific nomenclature; and an examination of this book shows that these views have been faithfully and judiciously followed. Witness the authors' golden silence respecting such names as *Anthophyta*, *Castalia*, *Unifolium* and *Hicoria*.

In describing the grasses the organs which we have learned to call the *outer* and *inner palets* are respectively termed *flowering glume* and *palet*. This change is in accordance with the usage of the *Genera Plantarum*, and of the Rocky Mountain Flora, and yet it hardly seems to be in the direction of simpler and clearer language. The homologies of the flower of grasses are still somewhat unsettled, and the old terms have done such good service in past times, that one would think they might be trusted a little longer.

The Gymnosperms keep their old position at the end of the exogenous class, and it is very certain that Dr. Gray would never have consented to any different place for them.

At the end of the text is a table of orders, with the number of genera and species, native and introduced, the exotic species being almost an eighth of the whole. Then follows a glossary of ten pages, giving brief but sufficient explanations of about seven hundred technical terms. In the Index one is glad to find the names of the species of the genera *Carex*, *Aster* and *Solidago*. The twenty-five plates consist of the old twenty plates of the fifth edition, with the addition of one new plate of grasses, and four plates of *Hepaticæ*, three of them borrowed from the edition of 1857, and one entirely new. D. C. E.

2. *On the Roots of Saprophytes.*—F. Johow in his memoir on Humus-plants free from Chlorophyll, (Pringsheim's Jahrbücher, vol. xx, p. 488) gives an interesting account of the organs of these peculiar plants. The roots and root-like structures are classified in a convenient manner, but the intermediate forms break down all sharp lines of demarcation. The range of plants with saprophytic absorptive organs is larger than is usually supposed. The orders Orchidaceæ, Burmanniaceæ, and Ericaceæ furnish the more numerous examples, after which comes the order Sentianaceæ. In every case the development of the root system is slight so far as its superficial exposure is concerned, in some instances there is almost a complete reduction. The underground organs have the power of forming buds which, after their unfolding, may be practically isolated from the parent stock. And, as examples cited by Drude and Irmisch show, some of there adaptations secure comparative immunity of the species from the destructive effects which would follow if propagation depended on the seeds alone. As might be suspected, the mechanical system in all these underground structures is of the least possible complexity. G. L. G.

3. *Genesis of the Arietidæ;* by Alpheus Hyatt. 238 pp. 4to, with 14 plates, Memoirs Mus. Comp. Zool., vol. xvi, no. 3. Published in conjunction with the Smithsonian Institution. — This memoir is the result of many years of work and thought, and

one of the most important of recent contributions to the subject of evolution. Like most American writers on evolution, the author attributes only a secondary importance to the principle of Natural Selection. In place of it he uses the expression physical selection, and explains it as "the production of suitable modifications by the action of forces which changed in a similar way large numbers of the same species, perhaps nearly all the individuals in the same locality or same habitat, within a comparatively limited period of time. The changes express the general tendencies to modification due to the response to physical causes on the part of the common radical and common organization. Another principle recognized is that whatever the order in the progressive development of a group, there is ordinarily the reversal of this order in retrogressive or degradational development. A third is acceleration in development, or the tendency in any variation in a progressive series to be inherited at earlier and earlier stages. A fourth is the fundamental principle of Agassiz, the basis of much of Mr. Hyatt's work, the parallelism between the steps in the development of an individual and those in the history of the group to which it belongs. These and other general ideas, brought out in Mr. Hyatt's essay of 1883, on the Fossil Cephalopods in the Museum of Comparative Zoology, are exemplified in various ways throughout this new elaborate work, and illustrated by excellent figures of all the species of the group of Ammonites under consideration—in which illustrations Mr. Hyatt shows that he is also an artist. An analysis of the work would require an article of many pages.

Among the principles one of a physiological character appears hardly to have its importance recognized by Mr. Hyatt, and is often overlooked by others. It is the familiar principle on which the breeder relies, the tendency of a variation, however begun, to become augmented by interbreeding, when the variety is one that admits of it. It is not "like producing like," but producing more than this; it is augmenting or accumulating in its effects, and often until the likeness in one character or another is largely lost; and it may affect thus either a generic, family, or tribal character as well as a specific; and all this by simply continued interbreeding, with healthful feeding and nothing more. Darwin began his work on the Origin of Species by illustrating the principle at length, but he failed to give it its true place because he assumed that variations in the individuals of a region would be too few for success without aid from natural selection. But if a variation takes place simultaneously or nearly so in most of the associated individuals of a region, as Mr. Hyatt holds, and as is probable amidst like environment conditions, then it may work as if under man's guidance, without natural selection or further physical selection. And the results under such circumstances will be permanent and normal, free from the extravagances of man's forcing work, because nature's healthful work is always slow and normal. This physiological law of *accumulative breeding*, while

leaving unexplained the origin of the variety, has long appeared to the writer to account for much in the history of a variation that is ordinarily attributed to outside conditions or natural selection. J. D. D.

IV. Astronomy.

1. *Transactions of the Astronomical Observatory of Yale University*, Vol. I, Part II.—Dr. Asaph Hall, Jr., has spent the larger part of four years' labor in the determination, by use of the Yale heliometer, of the orbit of Titan and the mass of Saturn, and in this publication are given his observations, and their reduction. The work has been done under the general direction of Dr. Elkin, who has charge of the instrument. There has been an uncertainty of about $\frac{1}{200}$ part in previous determinations of Saturn's mass, and the importance of this element in the theory of the planets made it very desirable that there be a new determination. Dr. Hall finds the mass $1/3500{\cdot}5 \pm 1{\cdot}44$, a result substantially agreeing with that of H. Struve, and with that of Bessel when the proper correction has been applied to Bessel's scale-values. Prof. Hall, from observations with the Washington refractor, had found by different methods four different values of the mass, three of which were decidedly larger than the one found by the Yale heliometer.

2. *The Algol System.*—Dr. Vogel, from his observations of the motions of Algol in the line of sight, finds (*Astron. Nachr.*, No. 2947) that the star before the minimum has at quadrature a velocity of + 5·3 miles (German) toward the earth, and after the minimum a velocity of − 6·2 miles. This gives a mean motion of the system − 0·5 miles, and an orbital motion of 5·7. Combining these with the observed laws of change of brightness and assuming that there are two bodies one brighter than the other moving in circular orbits about their center of gravity, he offers the following provisional scheme of the system.

Diameter of principal star	= 230,000	miles (German).
" companion star	= 180,000	" "
Distance of the centers	= 700,000	" "
Orbital velocity of companion star	= 12	" "
Masses, (assuming equal density)	= $\frac{4}{5}$ and $\frac{2}{5}$	of sun's mass.

3. *Rotation of Mercury.*—Prof. Schiaparelli announces in the *Astronomische Nachrichten* an interesting determination of the period of rotation of Mercury. This planet he finds behaves toward the sun as the moon does toward the earth, its periods of rotation on its axis and revolution in its orbit about the sun being equal to each other.

OBITUARY.

Chester Smith Lyman.—Prof. Lyman, Professor of Astronomy and Physics in the Sheffield Scientific School of Yale University, died on the 29th of January, at the age of seventy-six. He was graduated at Yale College in 1837, and at the Theological School of the University in 1840. His health failing and unfitting

him for his work as a clergyman, he made a voyage to the Hawaiian Islands in October, 1845, and the following year made observations on the volcano of Kilauea which led him to the announcement of a principle in volcanic action before unrecognized, that of "the bodily upheaving of the lower floor of the crater (an area two and a half miles long and two-thirds of a mile in mean breadth), by subterranean forces," to a height above its level six years before of at least three hundred feet. From 1847 to 1850 he was in California, and during this interval—that in which the discovery of gold was made—several notes by him on products of the gold region appeared in this Journal. In 1857, Mr. Lyman was appointed Professor of Industrial Mechanics and Physics in the Sheffield Scientific School. In 1870, on a division of the professorship, the title was changed to Sheffield Professor of Astronomy and Physics. Papers by him have been published in this Journal from time to time on astronomical and physical subjects. For several years Professor Lyman held the position of President of the Connecticut Academy of the Arts and Sciences. He leaves a son and two daughters.

John Huntington Crane Coffin.—Professor Coffin, the veteran mathematician and astronomer, died at Washington in January last, in his seventy-fifth year. He was born at Wiscasset, Maine, Sept. 15, 1815, was graduated at Bowdoin College in 1834, and was made Professor of Mathematics in the United States Navy in 1836. He served at sea and in nautical surveys until the time when the United States Naval Observatory was ready for active work. He was then detailed for duty in that institution, where Jan., 1845, he took charge of the Mural Circle. He gave his time exclusively to that instrument till 1851, when his eyes began to fail owing to the severe usage to which they had been subjected. He prepared the descriptions and discussions of the work with the Mural Circle, in the Washington Observations 1846–9. In 1853 he was ordered to duty at the Naval Academy, at Annapolis where he was engaged in instruction until 1866. In this year Professor Winlock was made director of Harvard College Observatory, and Professor Coffin succeeded him as Superintendent of the "American Ephemeris and Nautical Almanac." This peculiarly important office he filled for eleven years. Among his other contributions to astronomy was a memoir on the total eclipse of the sun, August, 1869. He was one of the original members of the National Academy of Sciences, and for several years was its treasurer. He received the degree of LL.D., from Bowdoin College fifty years from his graduation in Arts. He was a man of rare simplicity of character, kindliness of disposition, and devotion to truth.

Rev. Stephen J. Perry, S. J.—Astronomy has sustained a serious loss in the death of the genial and energetic Director of the observatory, at Stonyhurst. Father Perry had gone to the Salut Isles to observe the recent solar eclipse. The photographs were successfully taken, but he from exposure was taken ill of dysentery and died at sea five days after the eclipse.

PUBLICATIONS OF THE

JOHNS HOPKINS UNIVERSITY.

BALTIMORE.

I. **American Journal of Mathematics.** S. NEWCOMB, Editor, and T. CRAIG, Associate Editor. Quarterly. 4to. Volume XII in progress. $5 per volume.

II. **American Chemical Journal.**—I. REMSEN, Editor. 8 Nos. yearly. 8vo. Volume XI in progress. $4 per volume.

III. **American Journal of Philology.**—B. L. GILDERSLEEVE, Editor. Quarterly. 8vo. Volume X in progress. $3 per volume.

IV. **Studies from the Biological Laboratory.**—Including the Chesapeake Zoölogical Laboratory. H. N. MARTIN, Editor, and W. K. BROOKS, Associate Editor. 8vo. Volume IV in progress. $5 per volume.

V. **Studies in Historical and Political Science.**—H. B. ADAMS, Editor. Monthly. 8vo. Volume VII in progress. $3 per volume.

VI. **Johns Hopkins University Circulars.**—Containing reports of scientific and literary work in progress in Baltimore. 4to. Vol. IX in progress. $1 per year.

VII. **Annual Report.**—Presented by the President to the Board of Trustees, reviewing the operations of the University during the past academic year.

VII. **Annual Register.**—Giving the list of officers and students, and stating the regulations, etc., of the University. *Published at the close of the Academic year.*

ROWLAND'S PHOTOGRAPH OF THE NORMAL SOLAR SPECTRUM. New edition now ready. $20 for set of ten plates, mounted.

OBSERVATIONS ON THE EMBRYOLOGY OF INSECTS AND ARACHNIDS. By Adam T. Bruce. 46 pp. and 7 plates. $3.00, cloth.

SELECTED MORPHOLOGICAL MONOGRAPHS. W. K. Brooks, Editor. Vol. I. 370 pp. and 51 plates. 4to. $7.50, cloth.

THE DEVELOPMENT AND PROPAGATION OF THE OYSTER IN MARYLAND. By W. K. Brooks. 193 pp. 4to; 13 plates and 3 maps. $5.00, cloth.

ON THE MECHANICAL EQUIVALENT OF HEAT. By H. A. Rowland. 127 pp. 8vo. $1.50.

A full list of publications will be sent on application.

Communications in respect to exchanges and remittances may be sent to the Johns Hopkins University (Publication Agency), Baltimore, Maryland.

BECKER BROTHERS,

No. 6 Murray Street, New York,

Manufacturers of Balances and Weights of Precision for Chemists, Assayers, Jewelers, Druggists, and in general for every use where accuracy is required.

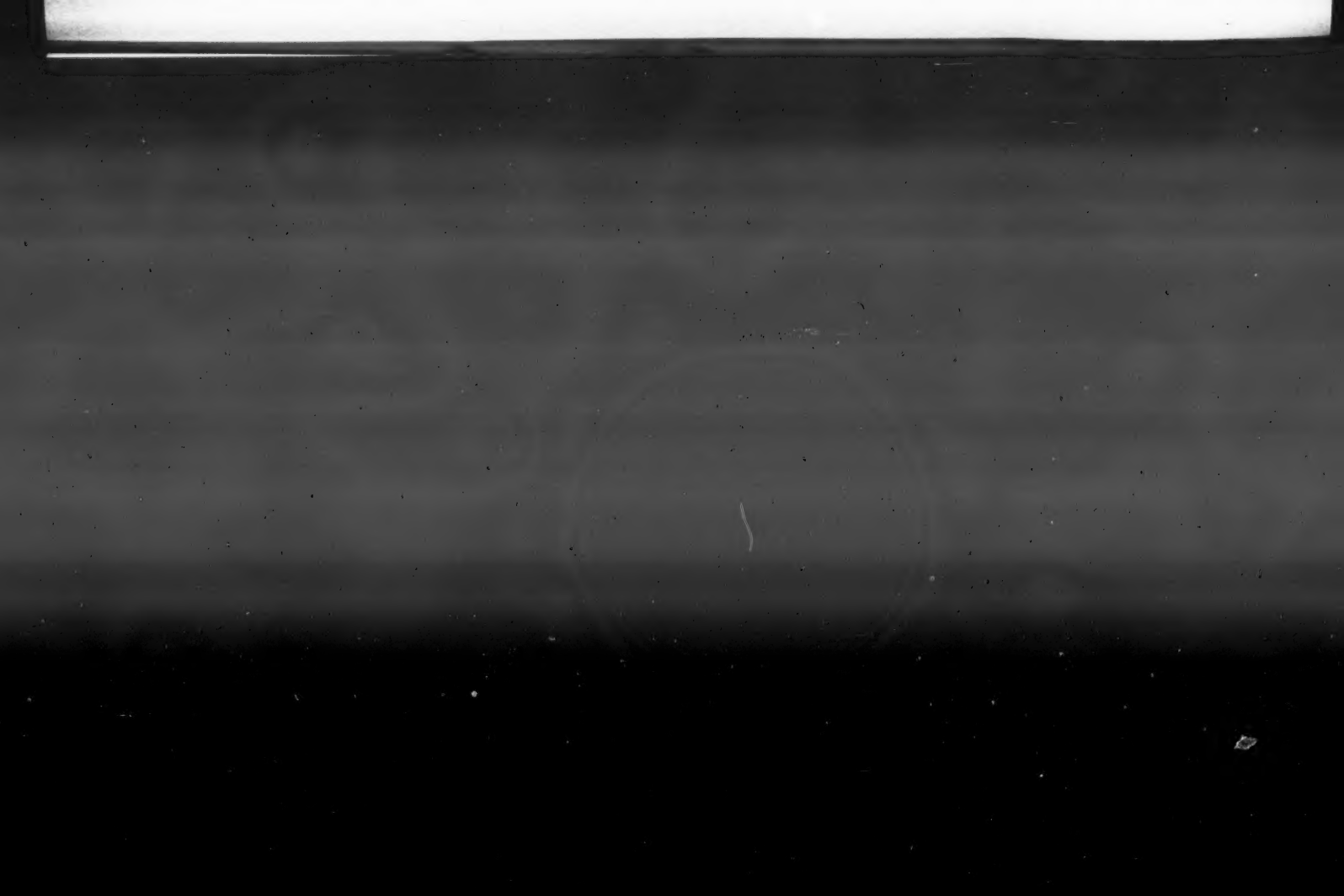
MINERALS

Sold, Bought and Exchanged.

Address **L. STADTMULLER,**

New Haven, Conn.

References: Prof. J. D. Dana and Prof. G. J. Brush.



ESTABLISHED 1885.

Most of my present stock was collected on my last two trips through the Southwest and Mexico, and great care was exercised in selecting only what was fine and interesting.

A *glance* at the following list will give an idea of recent additions.

Allanite.	**Fergusonite, Tri-hydro.**	**Pyrargyrite.**
Aegyrite.	**Gadolinite.**	**Tengerite on Gadolinite.**
Brookite.	**Nivenite.**	**Tengerite on Yttrialite.**
Cyrtolite.	**Opal-fire.**	**Thoro-gummite.**
Eudialyte.	**Polybasite.**	**Topaz.**
Fergusonite, Mono-hydro.	**Proustite.**	**Yttrialite.**

WILLIAM NIVEN,

Dealer in Scientific Minerals,

739-41 Broadway, New York.

CONTENTS.

Page

ART. XXII.—SEDGWICK and MURCHISON: Cambrian and Silurian; by JAMES D. DANA 167

XXIII.—Cretaceous of the British Columbian Region.—The Nanaimo Group; by GEORGE M. DAWSON 180

XXIV.—Celestite from Mineral County, West Virginia; by GEORGE H. WILLIAMS 183

XXV.—Method for the Determination of Iodine in Haloid Salts; by F. A. GOOCH and P. E. BROWNING 188

XXVI.—Mineral Locality at Branchville, Connecticut: Fifth Paper; by GEORGE J. BRUSH and EDWARD S. DANA. With analyses of several manganesian phosphates; by HORACE L. WELLS 201

XXVII.—Simple Interference Experiment; by ALBERT A. MICHELSON 216

XXVIII.—Improved Wave Apparatus; by JOHN T. STODDARD 218

XXIX.—Recent Rock-Flexure; by FRANK CRAMER 220

XXX.—Origin of the Rock Pressure of the Natural Gas of the Trenton Limestone of Ohio and Indiana; by EDWARD ORTON 225

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Lowering of the Freezing point of Metals by the addition of other Metals, HEYCOCK and NEVILLE, 230.—Chlorides of Selenium, CHABRIE, 231.—Production of Sodium carbonate by the Electrolysis of the Chloride, HEMPEL: Barium cobaltite, ROUSSEAU, 232.—Constitution of Dextrose, SKRAUP: Electrical Undulations, EDOUARD SARASIN and LUCIEN DE LA RIVE: Experiments with Hertz's Vibrations, G. F. FITZGERALD, 233.—Absolute Viscosity of Solids, Liquids and Gases, C. BARUS, 234.—Absolute Measurements in Electricity and Magnetism by ANDREW GRAY: Elementary Lessons in Electricity and Magnetism, SILVANUS P. THOMPSON, 235.

Geology and Mineralogy—Sedgwick and Murchison: Calciferous Formation in the Champlain Valley, E. BRAINERD and H. M. SEELY, 235.—Geological Survey of Canada, Annual Report for the year 1887-88, A. R. C. SELWYN, 238.—Manual of Palæontology, for the use of students, with a general Introduction on the principles of Palæontology, H. A. NICHOLSON and R. LYDDEKER, 239.—Elemente der Paläontologie, G. STEINMANN and L. DÖDERLEIN, 240.

Botany and Zoology—Manual of the Botany of the Northern United States, including the district east of the Mississippi and north of North Carolina and Tennessee, A. GRAY, 240.—Roots of Saprophytes, F. JOHOW: Genesis of the Arietidæ, A. HYATT, 243.

Astronomy—Transactions of the Astronomical Observatory of Yale University, Mass of Saturn: The Algol System, VOGEL, 245.—Rotation of Mercury, SCHIAPARELLI, 245.

Obituary—CHESTER SMITH LYMAN, 245: JOHN HUNTINGTON CRANE COFFIN, STEPHEN J. PERRY, 246.